



Learning from accidents: machine learning prototype development based on the CRISP-DM business understanding

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University for the Common Good

Joint CIB W099 & W123 Annual International Conference 2021

Changes & innovations for improved wellbeing in construction

9th-10th September 2021



W099

Safety Health & Wellbeing in Construction

Coordinators: Professor Billy Hare
Professor Fred Sherratt



W123

People in Construction

Coordinator: Professor Fidelis A. Emuze

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Introduction

These proceedings are published under the umbrella of the CIB, the purpose of which is to provide a global network for international exchange and cooperation in building and construction research and innovation. The CIB is the International Council for Research and Innovation in Building and Construction, and comprises a world-wide network of over 3000 experts from about 300 member organisations active in the research community, in industry or in education. They cooperate and exchange information in 35 CIB Commissions covering all fields in building and construction related research and innovation. These include Working Group 099 (Construction Safety, Health and Wellbeing) and Working Group 123 (People in Construction).

Objectives and Scopes of W099 (Construction Safety, Health and Wellbeing):

The Commission is committed to the advancement of safety health and wellbeing of construction workers. The tools necessary to accomplish this end include designing, preplanning, training, management commitment and the development of a safety culture.

A country's involvement with construction safety, health and wellbeing is influenced by factors like: varying labour forces, shifting economies, insurance rates, legal ramifications and technological development.

Objectives and Scopes of W123 (People in Construction):

The Task Group focuses on "boots on the ground" managers, professionals and workers.

The Task Group aims to involve representatives of employers, workers and governments, and researchers in both developed and developing countries, and aims to foster dialogue and collaboration.

Main research activities of the Task Group focus on various items related to people in construction, including: competencies, aging workers, gender issues, disability, work and labour conditions, H&S, work/life conditions and socio-economic issues, stress, respect for people, skills supply and employment relationships.

These proceedings are from the W099 and W123 joint conference, held on the 9th & 10th September 2021. This two-day conference was due to be held at Glasgow Caledonian University, Glasgow Campus, but became an on-line event due to restrictions on conference attendance due to the COVID-19 pandemic. The GCU Built Environment & Asset Management (BEAM) Centre hosted the conference, which is the fourth of its type held in the UK and the second in Scotland (2020 was also a Glasgow 'virtual' conference). Since 1996, this is the 29th meeting focused on at least one of the CIB groups' topics.

The conference provided an international forum for researchers and practitioners to put forward their research and ideas on how to improve safety, health, wellbeing, and the life of people in construction. The theme of this year's conference was "Changes and innovations for improved wellbeing in



construction”, aligned with the UN Sustainable Development Goals 3 (good health and wellbeing), 8 (decent work and economic growth), and 9 (Industry innovation and infrastructure).

Conference Statistics

88 abstracts received from 167 authors across 18 countries

13 rejected

3 withdrawn

75 invited to submit full paper (at this point a face to face will still planned)

Country	No. of Authors
Australia	21
China	4
Denmark	1
Ghana	1
Hong Kong (SAR)	2
Iraq	1
Malaysia	1
New Zealand	3
Nigeria	1
Oman	1
Portugal	11
Saudi Arabia	2
South Africa	42
Sri Lanka	2
Sweden	6
Turkey	4
United Kingdom	45
USA	19

44 papers received

37 accepted

2 withdrawn

4 rejected

1 industry paper

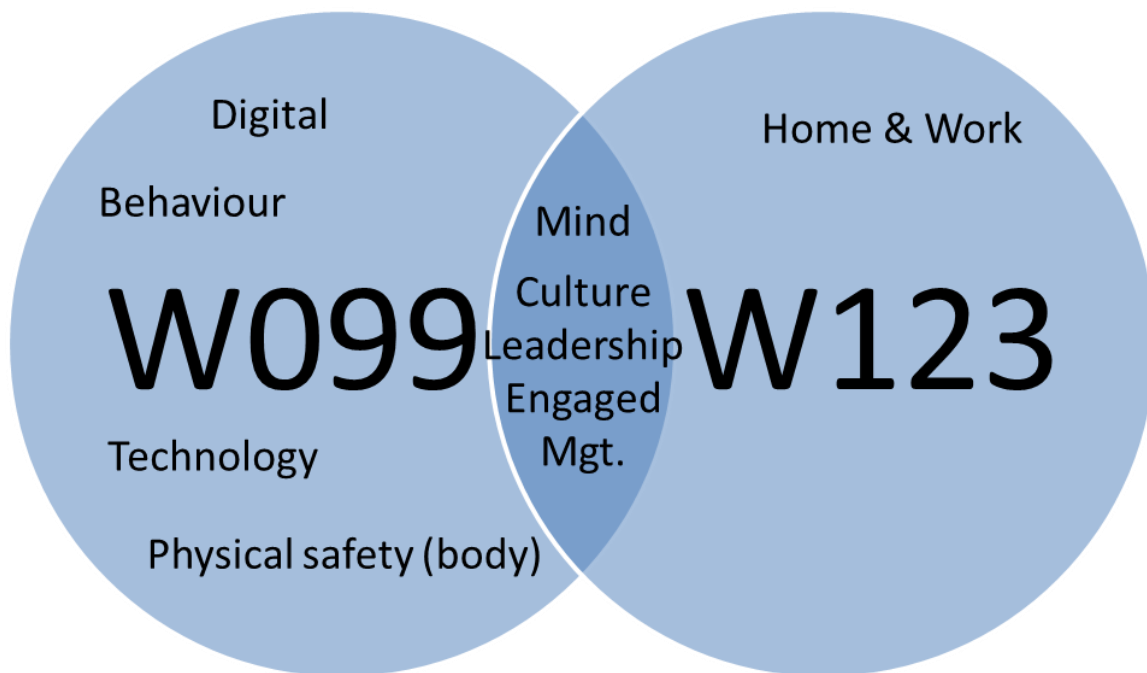
Accepted papers 89 authors from 8 countries

Country	No. of Authors
Australia	13
China	2
China (Hong Kong SAR)	2
Portugal	3
South Africa	13
Sweden	3
Turkey	2
United Kingdom	35
USA	15



Papers were divided into nine themes:

- Digital Innovation & Technology
- Culture & Leadership
- Human Factors & Behaviour
- Healthy Mind: Mental Health
- 'Flying' Innovation & Technology
- Healthy Body
- Management
- Healthy Mind: Stress & COVID
- Home & Work



Papers by themes

Most papers this year have been submitted to the W099 theme. Many straddle both W099 and W123, with 7 on mental health. However, there has been a dearth of submissions on topics such as gender issues, equality and diversity. Therefore, we should endeavour to promote more of these for future joint conferences.



Paper Awards

'Jimmie Hinze' Best Paper Award 2021

Safety Implications of Using UAVs in Construction: An Ethical Perspective

Mostafa Namian, Mohammad Khalid, Michael Behm

'John Smallwood' Best Paper Award 2021

Family Role Blurring and Conflict: The Case of South African Construction Professionals

Rita Zhang and Paul Bowen

Best Mental Health Paper Award 2021

Exploring Acculturation Stressors of Ethnic Minority Workers in the Construction Industry

Khursheed Ahmed and Mei-Yung Leung

Best Student Paper Award 2021

Risk myopia among UK construction workers: Refining the Prescription for our Safety Glasses

Ilya Andreev and Fred Sherratt

First runner-up

Jimmie Hinze Best Paper runner-up 2021 (Joint)

Cultivating a 'just' culture in construction industry to improve Occupational Health and Safety management systems

Meri Duryan, Jing Xu, Hedley Smyth

Risk myopia among UK construction workers: Refining the Prescription for our Safety Glasses

Ilya Andreev and Fred Sherratt

Best Mental Health Paper runner-up 2021

Improving Mental Health and Safety in the Construction Industry: A Study in Australia

Carol K.H. Hon

Best Student Paper runner-up 2021

Exploring Acculturation Stressors of Ethnic Minority Workers in the Construction Industry

Khursheed Ahmed and Mei-Yung Leung

We congratulate all those recognised here!

Professor Billy Hare

Glasgow Caledonian University, United Kingdom

Joint Co-Ordinator W099



10th September 2021

Dear Author

On behalf of the Joint CIB W099 & W123 International Conference 2021, held on 9th-10th September 2021, I can confirm that the Conference Proceedings will be formally published. (ISBN: 978-1-91418-801-5). I can also confirm that the Proceedings have a full table of contents, together with an index of authors, as well as statements indicating the importance of contributions from this discipline to the Conference.

All papers accepted for the Conference resulted from of a double blind peer review process at abstract and final paper stage by members of the International Scientific & Technical Programme Committee.

Best wishes

Professor Billy Hare PhD, BSc (Hon), BA, MCI0B
Conference Chair,
Joint CIB W099 & W123 International Web-Conference 2021
Deputy Director BEAM Research Centre | Construction & Surveying / SEBE



W123 (formerly TG59) People in Construction: Now and Tomorrow

The CIB task group on construction people (PiC) called TG59 held its first meeting on June 17th 2005 in Helsinki, Finland. The task group puts 'people' at the forefront of construction research. At inception, TG59 was a brainchild of the CIB through the active involvement of Dr Wim Bakens and the International Labour Organisation (ILO) through Dr Edmundo Werna. Although the task group was muted in 2004, it was only formally established in 2005 with Dr Jill Wells as the group's first coordinator. Dr Jill Wells, former construction specialist the ILO, served as the coordinator from 2005 to 2006. The objectives of the group in her tenure were twofold:

Bring together two kinds of researchers: those whose primary objective is to improve the industry's performance and see the focus on people as a way of achieving this; and those whose primary interest is in the lives of the people who work in the industry.

Create a dialogue between these two groups of researchers, from both developed and developing countries, to foster collaboration

The objectives mentioned above were expedited at the macro and micro levels of research focus. The macro-level involves a look into the labour market and its dynamics in addition to national and cross border migration. At the micro-level, the group's focus was on the reality of work on construction sites and views of the workers, the links between skills and productivity, future skill requirements, including professional and managerial skills, and the meaning of 'HRM' in construction. Ms Robyn Gordon took over from Dr Well in 2006. She focused on skills shortages, health, safety and welfare, change in attitude concerning productivity, leadership and resources, education, training and development, automation and technology and knowledge management. In 2007, joint international coordinators were appointed for the task group. The joint coordinators served for nine years (2007 – 2016). As joint coordinators, Prof Theo Haupt and Prof John Smallwood, expanded the research focus of TG59 while hosting conferences to attract emerging scholars to the group.

In 2016, Prof Fidelis Emuze took over the coordinator baton for TG59, emphasising people in the frontline of construction work. Thus, the research focus included respect for people, gender issues, older workers, workforce engagement, diversity, and wellbeing. The overarching idea is that people that binds the construction process together are the most valuable resource in the sector, and as such, their interests are essential research considerations. So, an intentional focus on 'boots on the ground' and frontline managers, professionals, and workers as the PiC came into being in the task group. Given that construction remains labour-intensive where people's contributions significantly impact performance, improving people's wellbeing is paramount. The task group that was recently upgraded to a CIB Working Commission (CIB W123) will build upon the work and antecedent of TG59. The work of W123 will involve scholars and practitioner identifying as employers, contractors, regulators, and all categories of people in construction operations (craft, technical, professional and managerial workers), in both developed and developing countries. W123 will foster dialogue and collaboration among PIC by expediting a range of forward-looking objectives, which include:

1. To create a network of interested and involved members in research into work (employment), people, and social issues in construction.
2. To bring into the network, scholars from outside the construction disciplines who are working on people issues.
3. To provide a forum for the exchange of ideas on social and people issues in construction.



4. To provide a forum for the exchange of ideas on people issues concerning Sustainable Development Goals (3 Health and Well-being, 4 Quality Education, 5 Gender Equality, 8 Decent Work & Economic Growth, 9 Industry, Innovation & Infrastructure, 10 Reduced Inequalities, 11 Sustainable Cities and Communities) in construction.
5. To provide a forum for the exchange of ideas on people issues concerning cyber technologies for fourth Industrial revolution (4IR) (Artificial Intelligence [AI], Quantum Computing, Internet of Things [IoT], Big Data, Blockchain, Cloud) in construction.
6. To provide a forum for exchanging ideas on people issues concerning physical technologies for 4IR (3-D printing, Robotics, New Materials) in construction.
7. To provide a forum for exchanging ideas on people issues concerning health disruptions in the form of pandemics and epidemics (inequalities, job securities, revised safe work procedures [SWPs]) in construction.
8. To provide a forum for the exchange of ideas on people issues concerning ethical reasoning in construction.
9. To identify critical issues for future research and possible sources of funding.
10. To disseminate research findings to a broader group of scholars and practitioners working in the field.

Professor Fidelis Emuze

Central University of Technology, Free State, South Africa

Co-Ordinator W123



Making History: the evolution of joint CIB W099 and W123 Conferences

W099 'Safety, Health and Well-Being in Construction', and W123 'People in Construction' first joint ventured for an annual conference in Cape Town, South Africa, June 2017, followed by Salvador, Brazil, August 2018, and virtually (Glasgow), September 2020. During the Triennial CIB World Building Congress, June, 2019, W099 and TG59 staged separate sessions. The 2021 virtual (Glasgow), conference continued this joint venture success.

The joint venturing has its origins in the scope of the respective commissions, resultant synergy, and dual allegiance of a number of members of the respective commissions.

In terms of scope, given that W123 focuses on people in construction issues, many are directly related to H&S, such as H&S itself, labour conditions, stress, work conditions, and work life conditions. Other W123 issues are indirectly related to H&S, such as ageing workers, and gender. Furthermore, recently completed people in construction research directed towards developing a W123 research roadmap, resulted in respondents identifying 53 issues relative to the top five people in construction issues, top five research priorities, and top five research gaps in their countries. Based upon the mean response, the top four issues were mental health, workforce well-being, workforce engagement, and H&S, which are all W099 issues, albeit in the case of workforce engagement, to a lesser extent. These findings also underscore the rationale for evolving the W099 name from 'Safety and Health in Construction' to 'Safety, Health and Well-Being in Construction'.

Professor John Smallwood

Nelson Mandela University, Port Elizabeth, South Africa

Member W099 (since 1996) and TG59/W123 (since 2007)

W099 & W123 Committee for 2021

Professor Billy Hare	Glasgow Caledonian University, UK
Professor Fidelis Emuze	Central University of Technology, SA
Professor John Smallwood	Nelson Mandela University, SA
Professor Fred Sherratt	Anglian Ruskin University, UK
Dr Kenneth Lawani	Glasgow Caledonian University
Dr Philip McAleenan	Expert Ease International, UK
Dr Ciaran McAleenan	Ulster University, UK
Dr Patrick Manu	University of Manchester, UK
Dr Emmanuel Aboagye-Nimo	University of Brighton, UK
Mrs Tres Hendry	Glasgow Caledonian University, UK



Scientific Review Committee

The peer review for this conference was only possible because of the voluntary contributions of experts from various countries. The editors are sincerely grateful to:

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Tariq Umar	Kingston University
Ned Umeokafor	Liverpool John Moores University
Rita Zhang	RMIT University



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ISHCCO Qualification Framework For Construction Safety Coordinators

**Alfredo Soeiro, Reinhard Obermaier, Manfred Mehl, Philip Baker, Jean-Piere Vanlier,
Erwin Bruch**

ISHCCO - International Safety and Health Construction Coordinators Organization
<http://www.ishcco.org>

Correspondence: avsoeiro@fe.up.pt

Abstract

ISHCCO (International Safety and Health Construction Coordinators Organization – www.ishcco.org) represents an European umbrella association of the national professional associations of Health and Safety Construction Coordinators (HSCC). One of the statutory aims of ISHCCO is to promote excellence in education, training and professional development in the countries of the national members. Since ISHCCO was founded in 2003 it has been working on the development of such a catalogue of criteria for the promotion and acceptance of qualification framework for HSCC. The ISHCCO qualification framework (IQF) developed enables benchmarking based on technical standards and European legislation complying with international and national criteria. IQF, like the European Qualification Framework, has three dimensions for the competences of HSCC: knowledge, skills and attitudes. What is described is the process followed to define these competences, the application of IQF for levels 5, 6 and 7 of EQF (technician, bachelor and master) and the connection with the European Directive 92/57 about temporary or mobile construction sites. The types of projects considered in IQF include requirements for simple projects, medium building construction and civil engineering projects and highly specialized construction projects or major projects. The target groups in construction are experts, institutions, professional associations, chambers of commerce, construction sector companies, authorities and building owner/clients. IQF can be used to define learning outcomes of HSCC training courses and respective contents and assessment.

Keywords : Competences, Construction Coordinators, EQF, Health & Safety, ISHCCO, IQF, Qualification Framework

DESCRIPTION

The European Temporary or Mobile Construction Sites Directive, 92/57/EEC, through national legislation in member states, places an obligation on clients to appoint safety and health coordinators for the both the preparation stage and the execution stage of a construction project [1]. The tables below describe the core knowledge, skills and Attitudes required by coordinators at three EQF levels, 5, 6 and 7 [2]. The relationship can be observed in Figure 1.

Each table of IQF starts with the standard EQF descriptor for the level, describes a typical project for which a person at that level might be an appropriate coordinator and presents some of the job names for that level of person that might be in common usage in some of the member states [3]. The functional requirements of coordinators are the same at each of the three levels it is the levels of skill, knowledge and Attitudes that increase at the higher levels.

Each table of IQF then presents the requirements on coordinators from the Directive, using the Directive Article numbers and beneath each requirement lays out the knowledge, skills and Attitudes that are required to discharge the function to that level. Each of the three tables starts with the functions of the preparation stage coordinator (Article 5) and then addresses the functions of the execution stage coordinator (Article 6).

The definitions of knowledge, skills and Attitudes used in this ISHCCO Qualifications Framework are adapted to Safety and Health Construction Coordination from the European Qualification Framework (EQF). The EQF definitions are:

- Knowledge – outcome of assimilation of information through learning. Knowledge is the body of the facts, principles, theories and practices related to a field of study or work;
- Skills – ability to perform tasks and solve problems;
- Autonomy and responsibility – the ability of the individual to apply knowledge and skills autonomously and with responsibility.

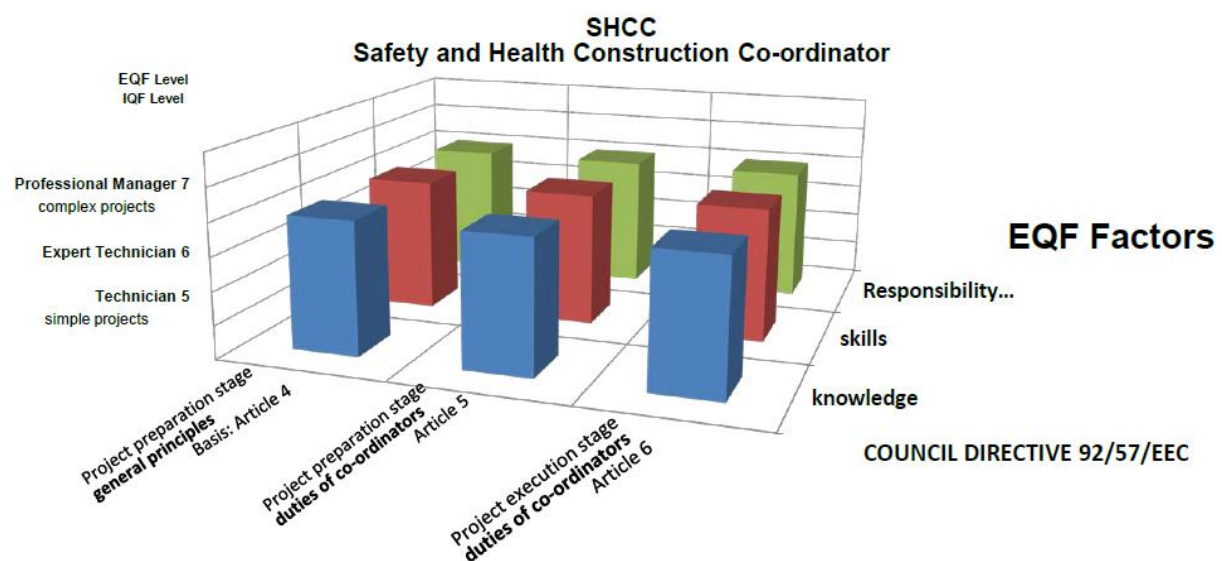


Figure 1 – application of IQF to the safety and health construction coordination

PROJECT BACKGROUND

These requirements expressed in IQF for HSCC are set in the context of health and safety construction coordination. The importance of understanding the design and construction processes to identify the interface risks between construction techniques. These can be best acquired with experience in design practice and on construction sites. The European Commission has produced a Non Binding Guide on the application of the Directive. In addition to the knowledge, skills and attitudes identified in IQF, HSCC wanting to work in European Union member states or in other countries around the world will also need to demonstrate that they understand and can apply the national requirements of the country of operation. An illustration of the requirements of HSCC can be that presented in Figure 2.

In terms of the project stages project stages different member states and countries have different definitions of the stages of a project [4]. In Figure 3 the stages are illustrated as described in the European Directive 92/57:

- The 'Project' starts when the client first makes contact with the construction industry and ends when the structure is complete.
- The 'Preparation Stage' starts at the start of the Project and ends when the role of the Preparation Stage safety and health construction coordinator is complete. This might be when the contractor starts work, when the design is complete, or at the end of the Project.
- The 'Execution Stage' starts when the construction work starts and ends at the end of the Project.

d) Qualification of the coordinator for safety and health matters

Good practices:

The competencies of coordinators for safety and health matters on a project should take into account the need to:

- have the requisite knowledge to act as a coordinator;
- have demonstrable skills and experience of similar projects;
- have sufficient knowledge of design and construction work, and of occupational safety and health issues specific to the project under consideration having regard to its size and complexity; and
- be able to satisfy the client that they have the resources successfully to manage the project's occupational safety and health risks for the work in question.

When assessing the competencies of a legal person, it is necessary to consider the competencies both of the organisation and the people it proposes to use on the project in question.

When assessing other stakeholders, the same broad issues of competence and resources are applicable.

Figure 2. From ISHCCO IQF [3]

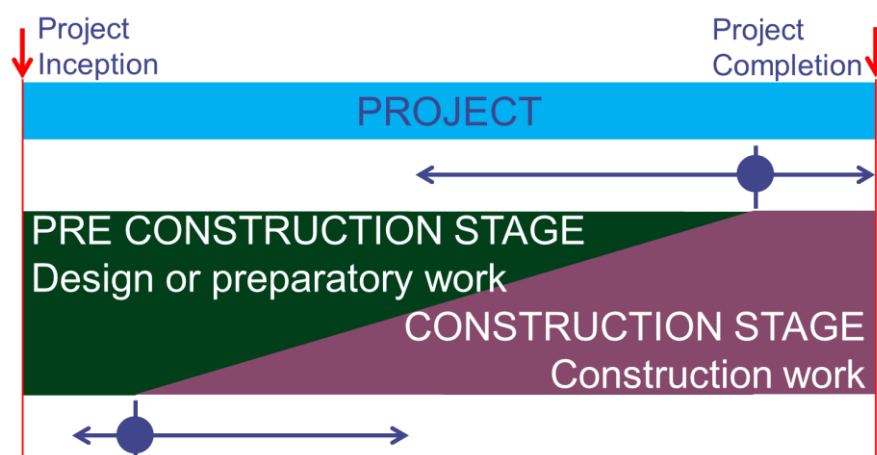


Figure 3. Project Stages



ISHCCO has produced the IQF with the contribution of a working group of members. The work was done in about four years and it was the result of several meetings held for a day dedicated to several steps towards the current IQF. Initially it was supposed to be developed as an accreditation tool for HSCC professionals. It was noted by association members that the task and responsibilities of carrying such a job of accrediting the professionals in each country was difficult due to the difference of procedures to be qualified as HSCC [5].

Intermediate step consisted in defining modes of assessment that were adequate for the different types of competences and various levels of HSCC activities. In this approach the tool TALOE was used to define for each type of competence adequate modes of assessment like peer review, case studies, multiple choice questions, problem based questions, etc. [6]. This phase was concluded and the proposals for evaluating the different competences were discussed and established. These are available for those interested in using these assessment methods.

The last phase consisted in developing training materials that could lead to the acquisition of the required competences. Some countries have their own training schemes based on local safety conditions and on construction practices. These training programs are different in terms of content, duration, periodicity, levels of qualification and definition of learning outcomes/competences. The idea of defining a common training program was researched but abandoned due to existing variations across countries. IQF has now this collection of training programs as an annex to the IQF so the choice of an adequate training program can be made.

LEVEL 7 HSCC Competences

Coordinator knowledge, skills and attitudes at EQF level 7 is presented as an example.

The level 7 Safety and Health Construction Coordinator (SHCC) according to IQF requirements for being qualified must have knowledge, skills and attitudes of the processes within the discipline of SHCC shown in the table below in addition to those for Levels 5 and 6. This can be achieved through training, experience or accreditation of prior learning.

EQF description of performances at Level 7 applied to the Safety and Health Construction Coordinator		
Knowledge (highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research; critical awareness of knowledge issues in a field and at the interface between different fields)	Skills (specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields)	Attitudes (manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams)
Example of projects: Process plant; complex geotechnical challenges; multi-storey above 25 metres/10 floors; bridge structures with pre-stressing; tunnelling; deep excavations greater than ten metres; dams		
Examples of functional descriptor: Germany – Engineer Portugal – Engineer		



Article 5(a) Project preparation stage: duties of coordinators

The coordinator(s) for safety and health matters during the project preparation stage appointed in accordance with Article 3(1) shall coordinate implementation of the provisions of Article 4 (*General Principles of Prevention*)

Knowledge	Skills	Attitudes
Understand the principles of ethical practice in construction safety and health	Demonstrate professional advocacy in relation to construction safety and health coordination	Justify construction coordination actions against organisational objectives
	Justify the principles and applicability of the tools and techniques available to measure risk	Utilise appropriate national and European standards to improve SHCC performance
	Develop internal construction coordination competence schemes	
	Apply the theory of organisational communication with respect to construction safety and health coordination	

Article 5(b) Project preparation stage: duties of coordinators

The coordinator(s) for safety and health matters during the project preparation stage appointed in accordance with Article 3 (1) shall draw up, or cause to be draw up, a safety and health plan setting out the rules applicable to the construction site concerned, taking into account where necessary the industrial activities taking place on the site; this plan must also include specific measures concerning work which falls within one or more of the categories of Annex II;

Knowledge	Skills	Attitudes
Understand the influences on the culture of an organisation on construction safety and health	Devise a construction safety and health coordination system for a project	Compare ranges of communication techniques and be able to select appropriate techniques for the intended audience
Understand the construction coordination policies of organisations working on a project	Develop your professional skills portfolio and recognise the importance of personal reflection	Communicate construction risks in the context of project risk
Understand general management techniques and how these can be used to deliver construction safety and health coordination	Devise goals and performance targets for safety and health within safety and health policies	
Adapt systems to incorporate diversity and inclusivity in the workplaces		



Article 5(c) Project preparation stage: duties of coordinators

The coordinator(s) for safety and health matters during the project preparation stage appointed in accordance with Article 3 (1) shall prepare a file appropriate to the characteristics of the project containing relevant safety and health information to be taken into account during any subsequent works.

Knowledge	Skills	Attitudes
		Communicate construction risks in the context of project risk

Article 6(a) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall coordinate implementation of the general principles of prevention and safety:

- when technical and/or organizational aspects are being decided, in order to plan the various items or stages of work which are to take place simultaneously or in succession,
- when estimating the period required for completing such work or work stages;

Knowledge	Skills	Attitudes
Understand the principles of ethical practice in construction safety and health	Develop your professional skills portfolio and recognise the importance of personal reflection	Justify construction coordination actions against organisational objectives
	Demonstrate professional advocacy in relation to construction safety and health coordination	Utilise appropriate national and European standards to improve SHCC performance
	Justify the principles and applicability of the tools and techniques available to measure risk	

Article 6(b) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall coordinate implementation of the relevant provisions in order to ensure that employers and, if necessary for the protection of workers, self-employed persons:

- apply the principles referred to in Article 8 in a consistent manner,
- where required, follow the safety and health plan referred to in Article 5 (b);

Knowledge	Skills	Attitudes
Understand the influences on the culture of an organisation on construction safety and health		Utilise appropriate national and European standards to improve SHCC performance

Article 6 (c) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall make, or cause to be made, any adjustments required to the safety and health plan referred to in Article 5 (b) and the file referred to in Article 5 (c) to take account of the progress of the work and any changes which have occurred;

Knowledge	Skills	Attitudes
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Understand the differences between monitoring systems	Develop change strategies to improve construction coordination on a project	Compare ranges of communication techniques and be able to select appropriate techniques for the intended audience
Understand the construction coordination policies of organisations working on a project	Utilise benchmarking techniques	Communicate the changes necessary to SHCC activities
Understand general management techniques and how these can be used to deliver construction safety and health coordination	Devise goals and performance targets for safety and health within safety and health policies	Challenge existing SHCC systems when necessary
Understand the concept of continual improvement in construction safety and health coordination	Interpret feedback from safety and health management monitoring systems	Communicate construction risks in the context of project risk
Adapt systems to incorporate diversity and inclusivity in the workplaces		

Article 6 (d) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall organize cooperation between employers, including successive employers on the same site, coordination of their activities with a view to protecting workers and preventing accidents and occupational health hazards and reciprocal information as provided for in Article 6 (4) of Directive 89/391/EEC, ensuring that self-employed persons are brought into this process where necessary;

Knowledge	Skills	Attitudes
	Illustrate how the systems devised meet statutory legal requirements in the jurisdiction of operation	Justify construction coordination actions against organisational objectives
	Develop internal construction coordination competence schemes	
	Apply the theory of organisational communication with respect to construction safety and health coordination	

Article 6 (e) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall coordinate arrangements to check that the working procedures are being implemented correctly;

Knowledge	Skills	Attitudes
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Understand the differences between monitoring systems	Explain the purpose of safety audits, their design and techniques	
Be aware of learning styles and their effectiveness in construction safety and health both for supervisors and the workforce	Interpret feedback from safety and health management monitoring systems	

Article 6 (f) Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall take the steps necessary to ensure that only authorized persons are allowed onto the construction site.

Knowledge	Skills	Attitudes
Be aware of learning styles and their effectiveness in construction safety and health both for supervisors and the workforce		
Adapt systems to incorporate diversity and inclusivity in the workplaces		

CONCLUSION

ISHCCO finds that having a proper set of terms of reference to evaluate who is capable of performing the HSCC tasks and jobs is fundamental to ensure society that professionals perform their tasks with quality. In an area like construction safety where accidents and fatalities rates are high it is a civic duty to assure that construction safety is coordinated by qualified and capable professionals [7].

The possible developments of the IQF are various. The first could be to become a standard for HSCC around the world. That would give possibility for mobility of HSCC across countries and would ensure that the competences have obtained quality levels. The second is that IQF can be adapted to the users acquaintance with competence frameworks using descriptors with concrete examples instead of competence definition. A third possibility is to specifically prepare IQF for different types of constructions like bridges, buildings, highways, dams, etc.

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SUICIDE IN CONSTRUCTION: EXAMINING UPSTREAM INDUSTRY INFLUENCES AND INTERVENTIONS

Ciaran McAleenan, Michael Behm, Gerard Ayers, Philip McAleenan

University of Ulster, Ireland
East Carolina University, USA
CFMEU Construction & General, Australia
Expert Ease International, Ireland

Abstract:

Suicide among construction workers is becoming a worldwide epidemic. Much of the literature and intervention strategies focus on construction site awareness, support and coping mechanisms, building a caring culture, and ways that construction companies can intervene and offer assistance. However, the construction industry is complex with multiple agents; just as we have found that eventual site safety is influenced by financier and designer decisions, the purpose of this paper is to explore and re-examine this topic from the perspective of project design influence and intervention. A literature review will examine current issues and intervention strategies. The authors are from Europe, Australia, and the United States where they will interview associations currently established to raise awareness and offer strategies around suicide prevention targeted at designers and owners. This paper makes the case for in-depth research in this area, where ultimately the findings will provide original and practical guidance to architects, engineers, financiers, and others distant from, but influential to, the actual construction site.

Keywords: Health and Safety, Mental Health, Organisational Culture, Suicide Prevention.

INTRODUCTION

Suicide; the very mention of it is uncomfortable, painful, distressful even. But it is around us, it affects us directly or indirectly and rather than thinking it is something deeply personal that we couldn't have foreseen, couldn't have prevented, it is timely to consider "what can we do to curtail this scourge?" This is not some academic treatise from the side-lines, this is deeply personal to all of us. Preventing or reducing the impact of a worker's suffering by what we do, upstream of the construction project is something at the heart of what makes us great designers. Who are we; which of us has influence at the early stages of a construction project and when do we ever consider good mental health as a part of the mix in making design decisions.

It is difficult, not just difficult to face, empathise or comprehend and it is challenging. Where to begin? What is there to understand? Surely suicide is so deeply personal and complicated in its root causes that those of us who influence great designs; clients, financiers, academics, etc., cannot be the ones to solve the problem? And the more we think like that the more suicide stays a problem in the construction industry.



BACKGROUND

Suicide among construction workers is being recognized as a worldwide epidemic. Data from Australia from 2001 to 2013 suggest suicide among construction workers remains elevated compared to other occupational groups and should remain a target for suicide intervention and prevention (Milner, 2016). Of the 6520 recorded suicides in Ireland in the period 2000-2012 a significant proportion were males construction workers; 1039 between 2008 and 2012 (CIF, 2015). In the UK, data from 2011- 2015 indicates that the risk of suicide among male labourers, particularly those working in construction roles, was 3 times higher than the male national average (Windsor-Shellard, 2017). According to Peterson et al. (2018), in the US, during both 2012 and 2015, the National Violent Death Reporting System data from 17 states indicated Construction is the occupational group with the second highest male suicide rate (43.6 / 100,00 [2012] and 53.2 /100,000 [2015]. The US study was expanded to 32 states in 2016 and again Construction remained the second highest occupational group with a suicide rate of 45.3 / 100,000 workers (Peterson et al., 2020). To put this as raw numbers, in the US for example, based on an annual construction workforce of over 6 million, in 2015 there were over 3,200 suicides among US construction workers. Compare this with 4,836 workplace fatalities for the whole of the US workforce (approx. 157 million) in the same year, (BLS 2020).

CURRENT INTERVENTIONS

One suicide is too many and considering how our upstream actions can be brought to bear in a positive manner, even if it prevents one suicide is a major success. If it prevents many then mega-success. But of course we can never truly know the full impact of any positive actions from upstream partners in the construction process, since if a worker decides not to take the path to suicide after all then we don't have a statistic to measure, but let us not lament that. That is the path to inaction. Suicide is a virtually invisible in society and in industry, partly due to the fact that we shy away from the act and the consequences. Remember! It is uncomfortable, painful and distressing to talk about. But to defeat this the conversations need to happen and they are.

In Victoria, Australia Incolink (2021) have a programme called 'Blue Hats', which is volunteer, worker led and worker driven. This programme is about looking after people, workers supporting fellow-workers, not counselling, just listening. Recently Dr Kylie King, Monash University, whose body of research focuses on the effectiveness of suicide prevention interventions for men and boys, has begun to support the implementation of and evaluate the effectiveness of the Blue Hats Suicide Prevention initiative (Monash University, 2020).

In the USA, the National Action Alliance for Suicide Prevention, among other activities, is working to change the conversation with research-informed messages that improves knowledge of the factors that offer protection from suicidal behaviours and which enhance wellness (NAC 2021). A more positive stance than looking at lagging indicators, which continue counting the bodies (to put it quite crudely). Also in the US, the Construction Industry Alliance for Suicide Prevention (CIASP) exists to provide and disseminate information, resources and training for suicide prevention and mental health promotion in construction with the goal of creating a zero-suicide industry (CIASP, 2020).

Australia's Mates in Construction (MATES) program is a suicide prevention and early intervention program delivering training and support to workers (Ross et al., 2019). In UK the Health in Construction



Leadership Group launched Mates in Mind, similar to the Mates in Construction campaigns, citing that workers in UK construction are 10 times more likely to die from suicide than from a job-site accident. Mates in Mind works to support organisations address mental health and wellbeing as it best fits their culture and ways of working (HCLG 2021). Connectors are front-line workers trained to identify and safely engage with people at risk and connect them to professional help. Results from Ross et al., (2019) indicate that MATES is an effective connector training in improving suicide prevention awareness, and help-offering and help-seeking through connectors. It is encouraging that the program appears to be enabling workers to overcome traditional barriers and attitudes to help-seeking through the positive stories of seeking/receiving help from industry peers.

The Construction Industry Federation in Ireland teamed up with Lighthouse (a construction industry charity) to launch the 'Help inside the Hard Hat' campaign raising mental health awareness across the island and offering helpline support and assistance across the construction community (Lighthouse 2020).

PROJECT OBJECTIVES

This research project is working to identify factors that can be considered early in the construction life, upstream of the construction activity, which key influencers can actively and with positivity and inclusiveness address. In some way addressing suicide in construction industry needs to be treated as you would a pandemic. We are all in this together! And every part of the puzzle, no matter how trivial or irrelevant it may appear has a role in the fight. Suicide is not an industrial disease, it isn't a blue collar accident. It doesn't matter that the highest number of suicides in construction is among blue-collar workers suicide is non-discriminatory in nature. Individual circumstances discriminate and exploit the vulnerabilities of those who feel they can no longer cope in society. And that is a failing of us all, for us all to reflect upon.

UNSDG Goal 8; to "Promote inclusive and sustainable economic growth, employment and decent work for all" (UN 2021) challenges Nations to help people cope with adversity, through social protection and basic services all the while promoting social cohesion and investing in community-led resilience. What we are talking about is a humanising of the construction industry. A socially responsible and ethically aligned approach to concept, design and delivery of infrastructure. This is not a new concept, explore the founding principles of professional codes of conduct (Engineering Council 2021) and the World Federation of Engineering Organisations (WFEO) (2021) to see how they refer to engineers' responsibilities relating to societal health and wellbeing.

UNSDG Goal 8 is not aimed at engineers, it is aimed at all the various influential forces in society, (groups/companies/communities) whose ethical and moral behaviour results from the interactions of the individuals that make up the collective, and which have the power to effect change. Where the compelling ethic is aimed outwards to the betterment of society, it may be broadly considered utilitarian, and in that regard what could be a greater challenge and a greater success than to play a major role in the eradication of suicide?

A serious yet horrifying question can be asked; is the problem of suicide in construction too large a problem for us to solve or too small a problem for us to address right now? Yet, whether it is too big or too small is not the issue, rather it is whether there is a failure to acknowledge or recognise that suicide is too high a price to pay for doing business.

Following on from this is the consideration of what our society in general and our industry in particular, really wants to do with the problem of suicide in construction. What interventions do we value and what are we willing to commit to, at the sharp end? Dekker (2013) said,



“The organizational blunt end is hugely important: it sets the constraints and creates the opportunities for doing things safely or not. It provides resources, rules, directives, production pressures, incentives and expectations, tools, technologies and lots of other things that directly impact on people’s ability at the sharp end to do things safely or not...”

In this context and for the purposes of this project, the term “safely” is defined as including “mentally safe”, not just physically safe and the project is focussed how to best place the emphasis on the “blunt end” of the industry and not just within the organization, i.e., from the perspective of project design, influence and intervention

MAPPING POTENTIAL UPSTREAM INTERVENTIONS

There are already many of the “upstream” support mechanisms in place (in varying degrees of course), e.g., Mates in Construction, IncoLink (in general) and IncoLink Blue Hats (in particular), as well as similar UK, Irish and US programs, and yet the carnage and loss of life continues, arguably unabated.

This project considers what can be offered or done that is different from what is already being done, because it appears, with all the best intentions and support programmes in place, we are still not able to really halt the slide of this suicide tragedy (or should it be described as an epidemic)? And perhaps we need to treat it like an epidemic. Halting/ceasing work when factors are identified, and not returning until some positive change can be proven/demonstrated to have been implemented at the “blunt end” of the organisational scale.

Table 1 outlines the current stage of mapping suicide triggers to potential interventions in the workplace. It is recognised that the causes of mental ill-health are varied and range in both severity and duration. Thoughts such as “life is not worth living” and suicide ideation are not uncommon but action on them is either not considered an option or is prevented as a result of protective factors, such as family. But there are times in some peoples lives when their mental ill-health reaches a crisis point when their thoughts and ideation become a viable alternative and those factors that were previously protective are no longer a strong enough preventer.

What triggers the crisis may be an ongoing worsening of their mental health, or it may be some new events that add to the pre-existing conditions. For some it may be a sudden change to circumstances for which they are unprepared that takes them from good mental health to the point of suicide very rapidly.

The workplace may not be the cause of the mental ill-health of a particular individual, but as a factor in their life it plays a significant role in determining whether their health improves or deteriorates, including whether there are workplace factors that are trigger mechanisms. In the manner in which workplace hazard assessments take into account worker age, fitness, health and vulnerabilities, the process ought to mental health and fitness as part of the assessment and the control measures that prevent harm and contribute to worker wellness are imbedded into the company from policy to operational levels.

Table 1: Mapping suicide triggers to potential upstream interventions



Acknowledged Triggers	Mapped to construction Industry and/or pressure points in construction environment	Upstream or Downstream related (using Dekker's definition) or both?	Current support programs and potential obstructions...	Suggestions of what may be done differently?
Work related stressors:	Yes	Both	Mates & Incolink etc are great – but not enough?	More realistic timeframes and programs.
Timeframe/scheduling	Yes	Both		
High job/task demand	Yes	Both	\$ Penalties and liquidated damages too high.	Less emphasis on \$ penalties and more on how to build & work with life / family balance.
Lack of job autonomy	Yes	Both		
Lack of worker voice	Yes	Both		More time off.
Conflicts (work)	Yes	Both	Timeframes/programs arguably too tight / unachievable.	Mandatory sessions at work for all workers for counselling (family, relationship, financial, substance addiction...).
Job insecurity				
Long hours				
Weekend work				
Large male population			Staggered handovers haven't helped coordinated/seamless completions.	Free Family days at work (no work undertaken) to show families what a worker does all day he/she is at work.
Poor female representation/interactions				
Macho mind set				
Workplace harassment			Being and admitting "vulnerability" should be an honor and a sign of strength – not a concept to be ashamed about or be seen as weak.	Less weekends (maybe a roster – every second weekend off...).
Racketeering/paramilitary activity				
Corruption				
Competences				Much larger mandatory ratio of female workers in/for our industry (working towards equal numbers...)



Personal	Yes	The work environment	See above	See above
Family/relationships breakdowns	Yes	contributes to these issues / triggers		
No time for relationships	Yes	(references will help validate this claim?)		
Too tired / too stressed	Potentially			
Poor communication (due to above)	Yes			
Loss of / no connection to family or partner	Potentially.			
Substance abuse				
Other addictive distractions to mask/hide the above: e.g. gambling				
Institutionalised clinical/medical diagnosis	Potentially			
Family stressors				
Financial issues (which also has personal implications...)	Personal Choice.		See above	See above
Debt – home, property, cars, motorbikes (other toys...)	Relationship breakdown issues.			
Private school fees	Personal			
Child / family support				
Poor budgetary advice				
Poor budgetary implementation				
Economically disadvantaged communities	Societal			



CONCLUSION

The specific aim of this project is to explore upstream sources of suicide risks in the construction sector and map ways that those with control of and/ or influence over these upstream factors such as designers, engineers, financiers could be part of a holistic solution to mitigate such risk. The product of this research project will be an upstream construction sector suicide risk factor review mind map and the end result of this project will be an identification and analysis of upstream risk factors of suicide in the construction sector. It will be utilised as a starting point to build upstream interventions that could augment the current focus of interventions at the worker and site level.

Having said that, it is important that we don't inadvertently or unintentionally "individualise" any of the identified problems, triggers and/or symptoms that cause suicide ideation, as well as any of the potential solutions. We know that workers just can't take time off when they want to and/or even need to, to sort out many of their "issues", especially when timeframes, budgetary (both personal and organisational) problems and restraints, relationship problems, work expectations, insecure employment contracts, etc., all impinge and in some cases prevents a worker's choice or option in seeking help. Any help/assistance for workers needs to be part of the overall work program, timeframe and hours of work that the worker is required to perform under their employment contract / agreement.

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Digitalisation for Occupational Health and Safety in Construction: A Path to High Reliability Organising?

Jing Xu, Meri Duryan, Hedley Smyth

University College London, UK

Correspondence: jean.xu@ucl.ac.uk

ABSTRACT

The occupational health and safety (OHS) performance has plateaued in the UK construction industry and the fatality remains three times the all-industry rate. Digitalisation of the construction industry offers increased productivity and new opportunities to reduce some OHS risks or better manage them. However, there is little in-depth knowledge on their processes and outcomes in terms of driving continuous improvement. This study deals with this gap by using high reliability organising (HRO) as a lens for obtaining insights into digitalisation for OHS management in construction. The aim is to investigate whether and how the implementation of digital technologies can help achieve high reliability of construction OHS. 21 semi-structured interviews were carried out, discussing how the process of digitalisation for OHS applied the five principles of HRO. The findings demonstrate that construction tends towards a 'quick fix' adoption process for technology, which falls short to sustain high reliability performance. Two complementary ways for enhancing digitalisation for OHS, based on HRO, were discussed: (1) integrating soft and hard systems to facilitate learning and interactions between hierarchies, at the firm-project interface and across organisations, and (2) empowering the workforce in OHS management through digital tools supported by appropriate systems at firm and project levels. More importantly, to achieve HRO requires the digitalising process generating collective mindfulness and a sense of caring rather than socially intruding among office and site workers.

Keywords: Digitalisation, high reliability organising, mindfulness, occupational health and safety.

INTRODUCTION

The UK construction industry has experienced significant occupational health and safety (OHS) improvement in the last 40 years. The declines of workplace fatalities and injuries were largely due to the introduction of OHS legislations, regulations and safety management systems (SMS). Yet the fatality rates have remained at a high plateau. An underlying assumption of prescriptive regulations and their enforcement is that OHS arises from following rules independently of the context (Hale & Borys, 2013). Consequently, the organisational OHS measures are mostly reactive to respond to external pressures from regulations and client requirements and focus on facilities and tools in individual projects. To break the OHS performance plateau requires a more proactive approach beyond compliance and a systemic perspective that considers the interrelations and interactions in the complex socio-technical systems. The specific characteristics of construction projects, particularly the physical, organisational and social decoupling of projects to parent organisations and the temporary multiple organisations, impose challenges in OHS management and monitoring (Harvey et al., 2019). It has been argued that the weak systems at the firm-project interface, across projects and organisational boundaries have caused difficulties in OHS knowledge management, communication, consistent performance and continuous improvement (Duryan et al., 2020). This is further exacerbated by the transactional business model adopted by construction firms where commercial considerations shape the project under and within which OHS is then addressed (Smyth et al., 2019).



It is believed that the development and application of digital technologies offers new opportunities to address the challenges and further enhance OHS performance in construction. There are many examples of usage of digital tools for OHS monitoring and management, from drones, virtual and augmented reality to wearable devices and robotics on construction sites. Whether and how their implementations can facilitate the OHS management process and drive continuous improvement needs to be investigated. The aim of this study is to examine the current process and outcomes of digitalisation for OHS in the UK construction industry, from the theoretical lens of high reliability organising (HRO) (Weick & Sutcliffe, 2015). HRO theory provides a means to manage OHS without sacrificing performance. The applicability of HRO in the construction and project management has been discussed in previous studies and the limits of the construction industry to achieve high reliability are identified (Harvey et al., 2019; Olde Scholtenhuis & Dorée, 2014). This study uses HRO principles to gauge whether and how the current digitalisation helps OHS performance in the UK construction industry.

OHS MANAGEMENT AND DIGITALISATION IN CONSTRUCTION

OHS is a major concern in construction. In the UK, one third of all workplace fatalities were from the construction industry, and around 4000 construction workers die each year because of work-related illness (HSE, 2018). This is echoed across many developed countries. There have been a series of step change improvements regarding OHS since 1970s. But the progress in the construction industry has arguably been slower than other industries. One of the reasons is transactional (Smyth et al., 2019). The competitive bidding drives construction firms to keep investment and expenditure low in order to secure works. The large tier-one contractors had no internal incentive to make improvement, which requires investment. Instead, OHS improvements are externally driven by legislations and standards. Clients and contractors set safety management systems, procedures and behavioural programmes to comply with external requirements. The result is that OHS has been regarded as a “bureaucratic burden” (Swuste et al., 2012, p. 1333), which involves complicated documentation and box-ticking exercise rather than valid analysis and learning from experiences (Harvey et al., 2019).

Safety management research has been progressing through several ages, being informed by engineering, psychology, sociology and anthropology. Hale and Hovden (1998) proposed the age of technology, the age of human factors and the age of management systems. The first age focused on technical improvements to mitigate risks and hazards. People and management related issues emerged subsequently, leading to a focus on the human behaviour and the demand for a more systemic approach, hence the emergence of various safety management frameworks (e.g., Haslam et al., 2005). The systems age is followed by an increased concern for organisational culture and relationships. Yet studies point out that the current safety management measures in the construction industry such as safety inspections are ineffective in terms of proactive intervention to prevent accidents (Saurin, 2016). Safety culture is also found to be hard to sustain in construction firms, especially under major organisational changes (Smyth et al., 2019). Safety is bolt on as an extra in construction project business and can be compromised when emergent events bring shocks to organisational systems.

An adaptive age has recently emerged in other industries and incorporates theories and practices of high reliability organising, resilience engineering and organisational resilience (Borys et al., 2009). The age of adaption represents a move away from bureaucracy towards developing organisational and human adaptability to manage the increasing complexity and dynamics of organisations and their environment. Workers’ knowledge and experiences are regarded as an asset to the organisation, which enable improvisation and adaption (Hollnagel, 2008). In this vein, some violations of written rules, or ‘work around’ are perceived as inevitable and sometimes necessary adaptations to local circumstances (Hale & Borys, 2013). For construction organisations where project workers are physically and socially decoupled to the parent organisation and subcontracting is prevalent, human adaptability needs knowledge and relationship management supported by the firm in order to ensure

both flexibility and consistency. Knowledge management system helps identify the gap between practice and procedure, capture and transfer the local knowledge across programmes and organisations, which increases the resourcefulness and resilience of the organisation. Relationship management fosters trust, openness and fairness across hierarchies, functions and organisations (Smyth, 2015). Mutual trust between management and operatives is key to flexibility in decision making especially during crisis or unexpected changes (Xu et al., 2021). A culture of openness and fairness encourages raising concerns regarding OHS and wellbeing issues at workplace (Duryan et al., 2020).

The development and application of digital technologies is believed to offer opportunity for better OHS management as they can help the monitoring and reporting of OHS data between project and organisation levels and facilitate learning about OHS issues including errors and near misses. Table 1 summarised the digital technologies in relation to construction OHS management in the literature review (e.g., Ahn et al., 2019; Antwi-Afari et al., 2019; Niu et al., 2019).

Table 1: An overview of digital technologies for OHS management in construction

Function		Technology						
		BIM	Wearable sensors	RFID, UWB, GPS/GIS, GSM, Bluetooth, WLAN, IoT	VR/AR/Computer-generated simulation	Computer-/Tablet-/Mobile-aided	Camera /Drone	AI
Design	Prevention through design	X						
Planning	Safety plans	X		X				
Monitoring	Fatigue/Stress/Musculoskeletal disorders		X				X	X
	Wellbeing: e.g., sleeping patterns		X					
	Location of resources, equipment and/or workers			X				
	Safety behaviour & activities		X	X		X		X
	Working environment			X			X	
Reporting						X		
Training		X			X	X		

HIGH RELIABILITY ORGANISING IN CONSTRUCTION AND PROJECT MANAGEMENT

HRO theories emerged through the study of day-to-day operations in the nuclear power plant, air traffic control and US navy aircraft carriers. Those organisations are characterised as ‘highly reliable’ because they perform exceptionally and almost error-free, despite that “they all operate in an unforgiving social and political environment, an environment rich with the potential for error, where the scale of consequences precludes learning through experimentation, and where to avoid failures in the shifting sources of vulnerability, complex processes are used to manage complex technology”



(Weick et al., 1999, p. 32). In this vein, safety is regarded as a dynamic non-event. Bureaucratic rules are seen as stifling whereas expert knowledge and adaptability supported by organisational systems and routines are needed to improvise and maintain performance, especially during the unexpected changes or crisis. The other common features include a high priority placed on safety, a learning orientation, a just culture that fosters openness, fairness and psychological safety, decentralised decision making in emergencies and proactively anticipating and responding to potential threats (Saunders, 2015). Weick & Sutcliffe (2015) summarised five principles of HROs:

1. Preoccupation with failure: an ongoing attention to weak signals of failures through continuous monitoring, proactive reporting and pre-emptive analysis of possible vulnerabilities. It is also a preoccupation with learning from experiences including failures, errors and near misses, which are treated as an indicator of potentially larger problems.
2. Reluctance to simplify interpretations: analysing failures, errors and near misses beyond human errors and direct causes; valuing divergent viewpoints that question underlying assumptions, uncovering blind spots and identifying changes.
3. Sensitive to operations: obtaining and maintaining the big picture of current situations. On the one hand, bottom-up communication from operatives is encouraged. On the other hand, senior and middle management needs to be actively in close touch with what is happening here and now in operations. Such information and knowledge can inform decision making in crisis but also forestall the accumulating of small problems that might lead to systemic failure.
4. Commitment to resilience: ongoing development of capabilities and resources to absorb, adapt, recover and learn from the adversity. Organisational resilience involves greater skills at endurance, adaption, improvisation and learning. This requires the support from organisational systems and routines but also individual competence and resilience, pointing to the importance of investing in both systems design and people.
5. Deference to experience: the tendency to shift decision-making to experts in the face of unexpected events. Subordinating written rules and hierarchies to expertise allows that emerging problems get quicker and better solution and capabilities are matched with the varying situations.

These principles demonstrate the organisation's capability to anticipate and contain unwanted situations and thus organisational mindfulness. Weick et al. (1999) defined organisational mindfulness as the "capability to induce a rich awareness of discriminatory detail and a capacity for action" (p. 37). Organisational mindfulness enables organisations and their employees to notice emerging threads, understand the interactions between actions within a system and act resiliently. Essentially, HRO theories promote a way of managing OHS and maintaining reliable performance through organisational and human adaptability enabled by good communication, learning, expert knowledge, trust and a strong organisational culture, rather than reducing it by increasing bureaucratic rules and control (Sutcliffe, 2011).

From the original contexts where safety is of prime importance and the consequences of incidents is far-reaching, the extent to which HRO theories can be translated to the construction industry has been debated in extant studies. Saunders (2015) compared the characteristics of the project environment and those of the operating environment that renders HRO. They pointed out some similarities between two environments, for example, high complexity, interdependencies between actions, multiple stakeholders with potentially divergent interests, uncertainties and information incompleteness. This is especially true for infrastructure projects or megaprojects that are undertaken in the public domain. A nuance in the debate is that in the original contexts safety and reliability are treated as equivalent concepts whereas in other industries such as construction they are not (Olde Scholtenhuis & Dorée, 2014). The concept of reliability is context-independent, "For some it [reliability] means the constancy of service; for others, the safety of core activities and processes" (Roe & Schulman, 2008, p. 5). Taking a pragmatic perspective, Olde Scholtenhuis and Dorée (2014) argue that reliability is important to all organisations in terms of improved performance and therefore HRO is applicable across a far broader range of industries. On the other hand, traits of the construction



industry that impose barriers to applying HRO principles were identified (Harvey et al., 2019; Saunders, 2015), including the project-based organising, temporary work processes, financial pressures, prevalent outsourcing and transient workforce. Such traits hinder effective communication between hierarchies, learning and knowledge transfer at the firm-project interface and across projects, investment in employees and leadership commitment. In particular OHS management, although construction is high-risk, the major concern is the frequency and rate of personal injury and fatal incidents. The safety-critical industries such as nuclear and aviation focus more on catastrophic events potentially causing societal impacts.

Despite the debates, HRO theories have been applied in the CPM to a wide range of topics (e.g., Brady & Davies, 2010; Saunders, 2015). This study focuses on OHS management and its digitalisation, using the five principles of HRO as the analytical lens. For the purpose of this study, reliability encompasses the consistency of service delivery, anticipation and resilience to shocks. It requires “the ability of organisations to plan for shocks as well as to absorb and rebound from them in order to provide services safely and continuously” (Roe & Schulman, 2008, p. 5). Safety refers to the way in which the organisation and project performs its mission without accidents, rather than an outcome of the project per se. Indeed, OHS incidents in the construction process can cause disruptions in the service delivery. HRO refers to systems, processes and procedures derived from the typical high reliability organisations that are critical to sustaining reliable organising and performance. Organisations, regardless of which industries they are in, can become highly reliable by creating the appropriate behaviour and attitudes supported by systems at multiple levels of organisation. In other words, they can be ‘reliability-seeking organisations’ that are enacted by mindful individuals and actions within the context of structure and routines.

RESEARCH METHODS

The research is explorative and uses qualitative methodology. 21 semi-structured interviews were carried out, discussing whether and how the digitalisation facilitates the organising of OHS in construction. As Table 1 shows that the range of technology available for assisting OHS in construction is considerable. This research is not to address the full range but to evaluate the range of issues emanating from the interviews. Data were collected from five types of organisation: institutions, professional bodies, client organisations, designers, and main contractors. Interviews were conducted with senior management, project directors, principal designers, health and safety managers, safety inspectors and site management. An interpretative approach is used to analyse data. The five principles of HRO (Weick & Sutcliffe, 2015) are used as an analytical lens to evaluate whether and how the current digitalisation facilitates the organising of OHS and enhances reliability.

FINDINGS

Overview of the digitalisation for OHS in construction

At the institutional level, OHS has not been embedded in the context of the industry. While the UK government has invested in digital innovation, OHS does not form an integral part. Most digital technologies are developed for productivity, and OHS is treated as an added value of such development. This is echoed by the organisation-level thinking that prioritises commercial considerations and treats safety management as something of a “bolt-on extra” (Smyth et al., 2019). It was commonly agreed that the main reason for minimal investment in digitalisation and OHS is cost. Contractors hold back on investment in order to appear more competitive in the bid stage. At senior and middle management levels, knowledge of OHS-related digitalisation is generally low and the competence to use and understand digital technology is problematic at all levels. In addition, the fragmented nature of the industry and the lack of systems integration between organisations impede industry-wide innovation and the collective capability to influence the institutional context including



the government and public policy. Therefore, both the institutional environment and the strategic leadership at industry level are not intentionally addressing OHS through digitalisation.

In terms of the current digital technologies implemented in the field of OHS management, they are contributing to one of the five categories:

1. Replacing people or at least complementing human capability for high-risk activities, such as drones, self-driving vehicles and sensors that detect and warn OHS hazards and risks in the working environment
2. Monitoring human activities and working conditions including locations, behaviour and working hours, such as cameras and wearables
3. Visualising risks and hazards in design, planning and training, such as BIM, VR and AR technology
4. Improving safety management systems through digitising the paperwork, enhancing data storage and visualising data, such as reporting applications on smartphones and tablets, online information sharing systems, cloud storage and performance dashboard
5. Removing work off site into controlled factory conditions where digital technology can be more easily applied.

Digital technologies were seen as individual solutions that do not contribute to overall performance in a number of ways. Nor data from different sources are linked with each other to build up a better understanding of OHS conditions. There is a lack of strategic and systematic thinking in the adoption of new technologies and the tendency to pursue 'quick fixes' in response to external forces such as safety inspection and client requirement.

Analysis of the digitalisation for OHS from the HRO perspective

Preoccupation with failure

An ongoing attention to possible failures requires continuous monitoring OHS leading indicators, detecting weak signals, analysing and learning from errors and near misses and sharing knowledge within and across projects and organisations. The need to apply BIM to aid OHS management in construction phase was stressed by regulators, designers and main contractors. The concept of prevention through design (PtD) has been promoted by Health and Safety Executive (HSE) under Construction and Design Management Regulations 2015 (CDM 2015). Designers are encouraged to identify and resolve OHS risks and hazards through design, or to highlight and communicate them with main contractors. BIM can be applied to facilitate this process. Yet two barriers to PtD were identified. First, designers generally have poor knowledge about the construction process and thus lack the ability to identify OHS risks. In fact, some designs are not buildable and might cause accidents on site. Second, the level of collaboration between designers and main contractors is low particularly after the design handover. There is minimal investment and commitment to project planning. The knowledge about how design is realised and influences construction OHS is not fed back to designers and clients to improve future works. The role of principal designer is set up to coordinate OHS issues in the project lifecycle but not necessarily the process of transferring knowledge across different parties. BIM has been grafted onto existing ways of working. Therefore, it is not surprising to learn from the findings that BIM is seen primarily as a tool for design and technical information processing and not a potential forum for improving OHS operationally.

Cameras and wearables offer opportunities for detecting weak signals of failures as workers' activities and site conditions can be monitored and analysed post incidents. But this is a reactive approach to managing OHS. To prevent injuries, fatalities and work-related illness requires active prediction and intervention in real time. This not only calls for advancement in data transmission technology but also the competence of people who observe the activities, which is built upon continuous education and learning from experiences including failures, errors and near misses. The adoption of VR and AR in



safety training in some large infrastructure projects was mentioned as an example of raising workforce awareness. One specialist consultant mentioned the high levels of dyslexia within the industry, and this may be a reason that visual technology resonates with practitioners. However, the positive impacts in the long term depend on the continuity of training that is updated as projects change.

More importantly, there is a lack of knowledge management system to support learning at individual and organisational levels, capture knowledge generated at individual and project level, generate and transfer generic knowledge for reuse at firm level and across projects. As one interviewee stated:

I'm going to be controversial. In construction, we're not interested in learning lessons, we're not interested in improving. What we're interested in is protecting our own reputation. So we're covered by lawyers. (Programme Manager of a megaproject)

Data that is collected is not done so systematically and the sector does not analyse it. The absence of systems causes difficulties to prioritise data that is useful for improvement and transformation and develop new capabilities to continuously improve performance. It was pointed out that the industry is repeating the same kind of accidents and incurring the same injuries due to the "unhealth culture about sharing information" (Head of Construction Sector and Policy of an institutional body). When it comes to information sharing inter-organisationally, the endeavour is focused upon successful stories. There is resistance to sharing experiences and learning from failures, errors and near misses. There are organisational reasons to enhance corporate image but also institutional factors that induce fear, distrust and blame cultures.

Reluctance to simplify interpretations

There was expressed concern that digital technology can be used as a 'black box' of which the output is taken for granted and hinders dialogues between people and at the human-technology interface. For what is inside the black box and how the output is produced is technologically complex to comprehend by users. This can further lead to rigid practice (act as the technology says) or inconsistent implementation of technology. To resist the tendency to simplify interpretations requires actively engaging with the workforce and using technology as a facilitator of communication.

When you do that [wearing wristband] you end up having a more detailed dialogue. Rather than being prescriptive and saying, "You're going to work X shifts and that's what the contract says." We engaged with the supply chain. Part of that engagement was to add this technology onto it to have a look after them. Eventually we changed the shift patterns to more benefit those individual groups. (Former Programme Manager of an infrastructure project)

In other words, data has to be managed in relation to understanding gaps between written rules and practices and recreating new practices to manage improvement.

It was recognised that digitising paperwork and cloud sharing enhance the ability to trace causes of safety incidents. Nevertheless, the digitised records tend to be used to find the 'culprit' to be blamed rather than to be systematically analysed to create knowledge and to be learned from. There are two challenges to be addressed in order to conduct systematic analysis of accident causes in construction. First is that technologies do not communicate with each other and therefore data from different sources is not linked with each other, which was mentioned by a researcher as a problem of "semantic enrichment". There is a potential for improvement in this vein by using text mining and machine learning in the analysis of accident reports. The second challenge is the cost and time pressures in the construction industry. As mentioned, because of the transactional nature of the business, senior management in construction has a history of pursuing 'quick fixes' or grafting on new technologies to existing structures and processes. The underlying assumptions are rarely challenged. It helps to make the sectors and organisational actors look engaged and proactive in the short run, but in the longer term the net result is a set of rigidities that are laid down and hold back effective adoption and iterative



refinement (). The last challenge, which was more commonly recognised in the interviews, is the blame cultures and the low level of trust between operatives and management and between institutional bodies and organisations. The fear of being blamed inhibited openness in reporting and the willingness to learn. This is worsened by the prevalent use of temporary contracts that make workers more vulnerable.

Sensitive to operations

There are ample examples where digital technologies can help the senior and middle management better understand what is happening in operations. The bottom-up communication about OHS issues from operatives are facilitated by the development of reporting applications available via smartphones and tablets. Safety management systems collect and visualise performance indicators. Large construction companies also invested in the information sharing system and individuals are required to share case studies monthly. Case studies are categorised in a number of ways such as project types and impacts. Drones are used for site inspection that saves time and cost as well. Yet, the level of engagement on both leadership side and operations side was reported as insufficient to bring about step change in performance. Some digital technologies pose problems as intrusive interventions. They can be perceived, indeed used, as monitoring devices by management that are unwelcome by operatives and indeed lead to pressures to intensify work rates that induce stress and fatigue, hence also exacerbate OHS. This type of action erodes trust and feeds perceptions of suspicion as to the motivations of management. Also, there is resistance to logging OHS issues. Apart from the trust issues and blame cultures as mentioned before, this can be due to other reasons, such as insufficient cost being built into bid prices to afford the time, awareness that the information will not be analysed and acted on in some cases, nor fed into an effective knowledge management system for re-use.

Deference to expertise and commitment to resilience

The last two principles, deference to expertise and commitment to resilience, lay the foundation to the effective implementation of digital technologies for OHS improvement. Despite that most OHS-related technologies are used by frontline workers, or at least need their inputs, the decision making about which digital tools to be adopted is largely top down from the senior management. This leads to that some technologies were perceived by operatives as not useful or intrusive and thus not consistently used. One reason for the reluctance of engaging and empowering the workforce is the perceived low competence among frontline workers. It was argued that to improve the effectiveness of digitalisation needs investment in people to raise their competence and responsibility of employing digital technologies to improve OHS. Yet individual responsibility alone is insufficient to induce transformation. Another integral part is the investment in organisational capability development and systems design to support learning, knowledge management and also relationship and trust, aligning to the long-term strategy of the organisation.

DISCUSSION AND CONCLUSION

The aim of the study has been to examine the process and outcome of digitalisation for construction OHS, from the perspective of HRO. The five principles of HRO theories (Weick & Sutcliffe, 2015), which are preoccupation with failure, reluctance to simplify interpretations, sensitive to operations, commitment to resilience and deference to expertise, were applied in the analysis. It has been found that digital technologies offer a major opportunity to improve and potentially transform OHS in construction. Yet the current way of adopting and implementing digital technologies falls short to realise long-term benefits for OHS and high reliability performance in projects and business. The findings point to two complementary approaches to achieve reliable performance. The first is to improve systems design to facilitate the creation and recreation of routines and procedures. Preoccupation with failures, reluctance to simplify interpretations and sensitive to operations



contribute to actively anticipating and identifying weak signals of failures and then intervening through a set of procedures (Olde Scholtenhuis & Dorée, 2014). In this vein, reliability depends on the development of processes, procedures and routines. Nevertheless, adherence to rules and procedures alone will not lead to continuous improvement. Reliability is the outcome of a continuous management of fluctuations in human interactions (Sutcliffe, 2011). The underlying assumptions need to be challenged and routines recreated as gaps between written rules and practices are continuously monitored, understood and shared between individuals, teams and organisations. This process requires good knowledge management to support learning and knowledge transfer at firm-project interface and across projects. It also requires good relationship management to nurture trust, respectful interactions and the awareness of how one's own actions fit into the larger system and with other people's jobs. Knowledge and relationship management systems contribute to the relational and social infrastructure of a mindful organisation. The adoption of digital technologies needs to invoke the rethinking through how the existing business needs to be re-engineered to optimise the implementation. It is based on the solid relational and social infrastructure that interrelations and integration between different forms of information and software can be explored and established. In other words, the soft and hard systems should be better integrated to enhance reliability. The second approach is to engage and empower the workforce in OHS management supported by the knowledge and relationship management systems. Working at the frontline can give operatives a clearer view of what are standard practices that are detrimental to safety, for example long shifts and working unsocial hours on site that induce fatigue and stress, which can pose broader challenges to current practices. Having such information needs an approach that encourages actors to mine and understand the data, before it can be usefully acted upon. In addition, different perspectives need to be embraced in decision making to avoid simplifying interpretations. This is supported by behavioural norms of respect, openness and trust, hence nurturing psychological safety to speak up about issues of concern, share one's own perspectives and ask other questions about their perspectives. Adaption and improvisation rely on individuals who have the competence to understand and employ the technologies for the benefits of their own OHS. Lastly, to achieve HRO requires the digitalisation process generating collective mindfulness and a sense of caring rather than socially intruding among office and site workers.

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LEARNING FROM ACCIDENTS: MACHINE LEARNING PROTOTYPE DEVELOPMENT BASED ON THE CRISP-DM BUSINESS UNDERSTANDING

May Shayboun, Christian Koch, Dimosthenis Kifokeris

Chalmers University of Technology, Sweden

Correspondence: shayboun@chalmers.se

ABSTRACT

Occupational accidents continue to be an unresolved problem in the Swedish construction industry, despite a whole range of routines, campaigns, education, management appraisals, authorities' enforcement, networks, and research in place. While registered accidents *are* less frequent, there is a widespread willingness to strive for better performance. A potential solution is to apply more robust data analytics to the large company occupational accident registers, complementing existing regular analysis. Machine learning (ML) can provide a promising solution for strengthening data analysis, and international prototypes of such systems are emerging. However, there is a need to appreciate local and corporate concerns, and the ML development method "Cross Industry Standard Process Development Method" (CRISP-DM) appears to offer just that. This paper aims to analyse experiences and challenges in using the first phase of CRISP-DM, i.e., "business understanding". The sociomaterial approach serves as the framework of understanding and is supplemented with accident research and ML development concepts. Methodologically, the paper draws on an ongoing research project to develop a ML prototype for occupational accident analysis. It quickly surfaced that CRISP-DM's "business understanding", while asking relevant questions in the company context (such as the goal for the model and the relative application), was too general to provide developmental guidelines. We, therefore, shifted from a top-down to a bottom-up approach, where knowledge on accident registration procedures and registered accidents became the starting point for iterative prototype development. Also, early challenges were to understand the registered data extracted from standard software with limited transparency, and tackle register entries of different quality. Apart from CRISP-DM's slightly idealistic approach to a company context, it is important to appreciate the classical decoupling between top management and (bottom) project levels in Swedish contractor companies.

Keywords: accidents, machine learning, Sweden, CRISP-DM, construction, accident register

INTRODUCTION

ML is receiving remarkable interest in safety research as a new approach to improve the prevention of occupational accidents (Goerlandt et al. 2020). The capability of analysing large amounts of accident reports appears to bolster this aspiration. However, preventing occupational accidents is a very mature discipline, which appears to function well alongside the continuing unsolved occurrence of accidents (Judson and Brown 1944, Hovden et al. 2010, Lingard and Wakefield 2019, Hasle et al. 2021). There is a risk of reinventing the wheel, repositioning the same prevention proposal repeatedly, disregarding central dynamics of the work environment context – as in Lingard and Wakefield (2019) and Hasle et al. (2021), proposing a better integration with design, project management, and operations management to lever accident prevention. Therefore, there is a need to appreciate the local and corporate context and their often-contradictory dynamics. ML software development appears as sufficiently malleable to meet exactly that requirement. In particular, the ML development method CRISP-DM is of interest, as it is one of the most used methods. The method of CRISP-DM starts with the "business understanding" stage for setting up developmental requirements and plan for the development and deployment stages.

Therefore, this paper aims to analyse experiences and challenges in using the “business understanding” phase of CRISP-DM to assure a solid contextual embedding and an appreciation of local dynamics. A sociomaterial approach serves as the framework of understanding, supplemented with accident research and ML development concepts. The context of a contractor company is indeed complex (Lingard and Wakefield 2019). Therefore, methodologically, the research adopts a bottom-up approach. The paper draws on an ongoing research project aiming at developing a ML prototype for occupational accident analysis.

Firstly, the paper contributes with an understanding that CRISP-DM’s “business understanding” is too general to provide sufficient guidelines for ML development – even relevant general questions of the company context (e.g., the goal for the business and the relative application) are indeed asked. We, therefore, shifted from a top-down to a bottom-up approach, where knowledge on accident registration procedures and registered accidents became the point of departure for iterative prototype development. Secondly, it highlights the difficulties in understanding registered data extracted from standard database software with limited transparency, and tackling register entries of different quality – which echoes previous research on the importance of the reporter’s interpretation (Dekker 2015, Jacinto et al. 2016). Thirdly, it appreciates the classical decoupling between top management and the building project level in Swedish contractors. Integrating accident prevention at the operational level is not a simple task (Hasle et al. 2021).

METHOD

The overall method is an interpretive approach (Alvesson and Kärreman 2007). A concept-centric literature review was conducted (Webster and Watson 2002) to review the status of ML-based solutions for accidents report analyses. The literature review was connected to the application of ML in analyzing reported accidents in the construction industry. For the empirical context, five interviews were carried out: four with safety engineers and one with a safety strategist at a high level in a Swedish contractor company. The questions for the interviews were developed towards the unfolding of the meaning of safety, accident response process, reporting process and quality, and the expectations from a ML-based prototype. Moreover, the ML questions and discussions were focused on developing a data-driven prototype, inspired by the business understanding framework of CRISP-DM and the recommended practice (RP) framework (DVN GL AS 2020).

THE STATUS OF ML DEVELOPMENT METHODS

ML is generally defined as the exploration of algorithms enabling computing systems to “learn” and make data-driven predictions by building a model from a sample dataset (Curtis and Scheinberg 2017). Computer systems that utilise ML automatically improve through experience (i.e., new domain data) (Witten et al. 2017, Portugal et al. 2018). ML is frequently classified into supervised, unsupervised, and hybrid (Kakarla et al. 2021). Supervised ML algorithms are “trained” and validated using labelled datasets with known reasoning of the application domain (Kakarla et al. 2021). Unsupervised ML analyses unlabelled data under assumptions about its properties (Jordan and Mitchell 2015) by finding hidden patterns in the data and developing models “on its own” (Portugal et al. 2018). Hybrid ML mixes several approaches (e.g., semi-supervised and reinforcement learning) (Gerard 2021).

There has been an increasing interest in developing ML models and prototypes for the analysis of occupational accident data within construction. Such recent prototypes can be largely categorized according to their purpose, i.e., classification, prediction, or information retrieval. For example, ML prototypes have been deployed for the classification of accident categories (Kang and Ryu 2019, Zhang et al. 2019), severity, type (Shrestha et al. 2020, Zhong et al. 2020), energy source, and related upstream measures (Zhong et al. 2020). When it comes to prediction, ML models have been developed to predict accident outcomes (Ayhan and Tokdemir 2019), the likelihood of fatality (Choi et al. 2020), and accident severity (Zhu et al. 2021). Finally, a ML prototype for information retrieval covers the hazard object and position, work process, and accident result (Kim and Chi 2019).



In all of the aforementioned (and other) cases, the developmental process (incl. the choice of algorithms, dataset preparation, and modelling) was mainly goal-informed. However, the contextualization of this developmental process and its constituents (e.g., the algorithms) emerges as a major issue. The conceptual matching of algorithms to a specific occupational accident-related problem and dataset is rarely carried out; their suitability is not contextually evaluated – the algorithms are rather selected on an experimental, trial-and-error process, lacking a systematic development method. Such an approach could lead to choices based solely on performance metrics (accuracy, error) prone to overfitting and not necessarily capturing contextual specificities. Moreover, “repairing” datasets (e.g., under- and oversampling) is sometimes employed without considering whether datasets maintaining their initial properties (such as sparsity) can represent reality and inform the algorithms more meaningfully. Things are even exacerbated by an overreliance on internal validity testing and a lack of external testing on performance metrics and prediction accuracy. In summary, the development of ML prototypes for the analysis of occupational accidents in construction largely lacks, in most cases, the framework of a specific methodology.

An exception to this rule can be the development of ML prototypes according to the CRISP-DM methodology; CRISP-DM dictates a series of six steps (business understanding, data understanding, data preparation, modelling, evaluation, and deployment) (Martínez-Plumed et al. 2019). These steps can account for a contextualization of the developmental process, starting with the initial step of business understanding – and thus offer a way to ameliorate the previously mentioned shortcomings. CRISP-DM can be considered to go beyond goal-directed development (Martínez-Plumed et al. 2019) by introducing systematic steps aiding in a conceptual systematization and mitigating the dependence on a solely experimental basis. Based on the organized steps of CRISP-DM, other industrial models have emerged, such as RP (DVN GL AS 2020). The latter claims to be differentiated from CRISP-DM by the usability in applications comprising data-driven models developed using other processes while focusing on risk assessment and quality assurance of data-driven applications (DVN GL AS 2020).

Business understanding

The business understanding aims to define the business objective (Chapman et al. 2000), including defining the client’s goal and capturing the organization’s business status. In more detail, this step corresponds to different subtasks: determine business objectives, assess the situation, determine data mining goals, and Produce project plan (Chapman et al. 2000). The same steps are followed in RP but add concrete documentation requirements, including commercial, safety, and social constraints anticipated in the deployment (DVN GL AS 2020).

Determine business objectives

In this step, the analyst uncovers what the business goal for the customer is and answers collateral business questions related to the primary goal. Objective or subjective success criteria are decided from the business point of view (Chapman et al. 2000). RP introduces a so-called value proposition statement, which documents the intended user and why and how the application would be used. The value proposition might be documented together with the business context in the form of use cases and users’ stories (DVN GL AS 2020). The business context, objectives, and success criteria should be sufficiently and objectively defined at the end of this stage.

Assess the situation

Assessing the situation involves a detailed analysis of the resources, constraints, and assumptions related to the business objectives. This step should result in a series of outputs, including a list of all possible resources, a setup of project requirements, measurable and subjective expectations, risks of project failure, terminology, and cost-benefit analysis from a commercial perspective (Chapman et al. 2000). RP (DVN GL AS 2020) views this step as a risk assessment of the intended and unintended uses of a deployed application. It is suggested that this step can be done in two different iterations, also connected to the followed step (determine data-driven goals). Identifying and documenting



stakeholders, available data resources, project requirements, project assumptions and constraints, suitable terminology, project risks, and the application design can be related to the modelling goals (high-level assessment). Defining the cost-benefit, failure modes, and legal and ethical consequences can be related to the modelling step from a technical-focused point of view (low-level assessment). All the deliverables of this step are required to be sufficiently identified and understood.

Determine data mining goals

This step must determine the objective of the data mining process in terms of data analytics linked to the business goal (Chapman et al. 2000). According to RP (DVN GL AS 2020), this stage requires close collaboration between domain experts and data analysis experts. At this point, the desired predicted target should be defined clearly together with the modelling success criteria – either objective, based on a low-level assessment, or subjective, based on a high-level assessment.

Produce project plan

A realization plan for the data mining goals is prepared to specify steps, resources, and possible iterations – while also developing a list of data analysis tools and techniques (Chapman et al. 2000, DVN GL AS 2020).

MAPPING OF THE CONTEXT

We are mainly interested in how accident prevention is embedded in the business setting when mapping the context. The contractor operates a project-based organisation. The building project is the most important value and turnover generator and cost transformer. The different building projects are produced in portfolios placed in divisions with slightly different business objectives, i.e., civil works, residential buildings, office buildings. The project commences with a contract with a client. The Health and Safety (H&S) work commences by documenting the way H&S will be organised in the project in a bid for the customer. Typically, no risk analysis is carried out by the safety engineers (SEs) this early; however, this is done once a contract is obtained. A particular job role, called BAS P (educated in design safety), is part of this process. From the beginning of work planning, the SEs inspect the plans with a H&S perspective. During production, the safety representatives (the so-called BAS U personnel – basic education for production) are responsible for a particular part of the building project and the building process. They collaborate with the on-site H&S, Quality, and Environment (HES) manager and the SEs. Together, they constitute a horizontal element of the H&S organisation and support the similarly horizontal building processes. H&S work is thus organised close to the single building project. Apart from this horizontal element, the company also encompasses a vertical hierarchy, where H&S is attached to several organizational levels. A central H&S unit is part of a corporate management HR unit. HES units are adjacent to several organizational levels. This cross-organizational H&S apparatus works with behaviour issues, analysis and reporting, digitalization, and developing directives. In it, it is a common perception that accidents are mostly due to behaviours, so efforts are targeting this issue. Another workstream is related to analysing and reporting, as well as digitalization, driving projects, and the way the company benefits from machines and innovation. The third workstream is related to developing directive processes and procedures.

The meaning of safety at the contracting company

At the case company, all four safety engineers (SEs) answered that safety in the organization means that everyone should go home safe and injury-free after a working day, and planning for that is the most important thing. One of the respondents indicated the difference between what safety means in the higher levels of the organization and on the site management level. On the higher levels, there is much talk about safety coming first, changing attitudes and behavior – while for site management, prioritizing different tasks and meanings affects many skilled workers.



A normal working day

A general remark regarded the respondents' thinking about the effect of COVID-19 on a "normal" working day. For some of them, working from home seemed abnormal. Before the pandemic, a normal working day involved the planning for project safety, safety support to site management and production personnel, follow-up on risk documentation, contact with site and project management, and discussing with the workers about the work environment and the reason protective equipment should be used. The project's risk assessment and work preparations must be ready, especially for those performing the work. There is a knowledge repository of tips and checklists of different subjects and tasks to help with planning. Often, if it is too cumbersome to search from the list, the site manager can ask the SE about the required information. Besides coordinating other tasks (such as the site economy), balancing what to take in and what to leave out is needed. It is better to use own knowledge first and then utilise the checklist to see if something was forgotten – the level of experience might determine how much of the checklist is needed.

The response of the event of an accident

The accident response routine is taken more seriously by the organization. There is a requirement for yearly training in the response process – although a respondent had not witnessed a severe accident in six years. The response depends highly on accident severity. In severe accidents, taking care of the injured comes first; people on-site also need attention to discuss the reasons and be involved in the investigation – for fact-checking, coming up with ideas for future prevention, and getting support in case of psychological shock.

The reporting of accidents

Accidents are reported internally through digital registering software. The responsible site manager initially does the registration, but the SE gets involved when needed. The reporter estimates what to fill in (e.g., a description of the event, information about the injured, prevention measures) and what to leave out. Most importantly, there is a list of fully defined accident causes, besides the possibility to comment in free text. In the portal, it is preferable to use the already defined options, as this allows one to look into the related statistics. The interviewee did not see the way free text can be used.

In severe accidents, the software allows for five causes and five prevention measures that need to be filled in (not needed in less serious accidents). The interviewees said that the reporters fill in what they think the cause is and, most importantly, relevant prevention measures. For deciding about those, one of the interviewees said that the first thing is thinking about the individual. The individual is responsible for planning and thinking; then, the company must provide safe work conditions and create a safety culture that emphasizes planning and knowledge sharing.

To decide on accident causes, the work environment plan helps check whether the work preparation was filled out properly and the risks were carefully estimated. However, there is a chance that all procedures were followed through properly, and the causes were person-related instead ("faulty acts"). The software can also guide on causes, but the filling in of information can differ according to the person doing it. Even if the causes and prevention measures are evident in the reporter's mind, this does not necessarily translate to a detailed enough description. One of the SEs describes their reporting as detailed so that anyone who reads the report can understand what happened – and added that it is crucial to go down to root causes and not stay at the surface level. The "5 whys analysis" is used as an easy and quick way to narrow down to root causes and come up with helpful prevention measures. Nevertheless, not all reporters are experts in root cause analysis; therefore, in very serious accidents, SEs come in and help with unfinished cases and more careful root cause analyses. Also, for many of the reporters in the portal (e.g., site managers), the human factor is the main cause – they thus do not what has caused the respective person to act this way.



Status of the data use and safety objectives

The accumulated accident reports are used in reporting key performance indicators by following statistics – but mostly on accidents that were severe or resulted in absence. In a recent use case, a score card scheme was used to report the event type and find certain risk categories in different parts of the organization. Another use case to planning to purchase personal protective equipment (PPE) based on analysed accident reports. The company uses the Bowtie model for analysis, because it wanted to work with high-risk areas and detect where barriers can be set to prevent those risks from happening. As part of the reporting assurance, the reporting of severe cases is always secured by SEs. Otherwise, H&S managers keep track of their area and support the reports of single cases, besides following up with the safety function group. This indicates what needs improving, training, communicating, or developing IT tools. The focus for both severe and less severe cases is on the reduction of their frequency.

The value of reporting of accidents and improvements

The interviewees agreed about the value of learning from reporting and not experiencing the same accidents again – acknowledgement the importance of reporting and learning, taking out statistics, sharing the knowledge, identifying risks, and planning the resources for similar work steps. SEs also wish to report social-related issues, usually not part of the routine, such as harassment. There are risks when people do not feel good psychosocially. This is something that needs to be worked on within all workspaces across the sector. It is not easy to see and spot this type of situation, which is a risk for individuals and groups. However, another SE pointed out that reporting negative/positive observations, incidents, and accidents is a routine. In that way, the portal seems comprehensive for all categories – but it would be good to add safety rounds within the reporting software. Another comment about additional reporting was that people do not always want to report – e.g. when the accident is the person's fault.

Improvement in the safety process for accident prevention support

Registering more events (incl. observations) can improve the reporting status, by making reporting faster and better in handling registered cases and coupling that with feedback and prevention. With more reporting and feedback, the work becomes more proactive and safer – e.g., when handling machines and material.

One respondent mentioned that people on site should follow what was decided. There are prevention packages, but they are not always followed, mostly because people want to do the work first instead of taking more time for safety-related preparations. The respondent called this the “I will just do this first” syndrome. Another SE thought there is a need for better planning, but otherwise, all the tools and processes exist – just not fully used. The SE had a generally positive outlook, as in the last six years, the organization was more focused on safety, even resulting in zero accidents recently.

Value proposition

The safety strategist indicated that the company is quite advanced in collecting H&S data but still far from where it aims to be. The digital reporting software was introduced five years ago (a short period for a large company), but the company only started using the data and investigating its utilities, which creates more needs. Moreover, data quality and precision still need improvement, and only looking at the data and not reflecting on it can be suboptimal.

The company's top long-term priority is on behaviour, which according to the accident report statistics, is the most common cause of both minor and severe cases. Behaviour is hard to affect because the end-user is always a person, but the H&S organization, especially the SEs, can exert such an effect. Furthermore, fatalities are aimed to be at the level of zero.



ML potential

In this part, the SEs were asked about their view of ML potential in analysing accident reports and their tasks. At the beginning of this set of questions, ML was briefly described for the respondents.

One SE mentioned that there was potential in extracting statistics of what had occurred in incidents, observations, and accidents, grouping them according to the case or subject, and gathering all possible prevention measures instead of speculating on how to solve a problem. Double-checking whether something was forgotten can also be possible support. On the other hand, two respondents thought it was difficult to say what ML can offer for their work process – but one added that through all data across the whole company, it might be possible to pay attention to work steps or work tasks where there are many accidents or many people injured.

The question was then reformulated to be more general about what a needed area of support could be. One SE answered that, in general, a lot of the work is about attitude and the way of thinking. It will be good to have tools to present information about the risks to the production people, make it more relevant, and even visualize it (pictures, animation) and engage them in their own work's safety processes. Alternatively, there is much to be learned from negative and positive observations and finding the reasons behind not following the rules, even though they are known.

When SEs were asked whether they wish to see their proposals as digital applications. One answered that everything is already digital. Another mentioned that the most important thing about a digital tool is that it is practical, it functions fittingly with the activities, and it provides something new – not only being something that needs to be done because the system requires so.

Proposals and ML risks

From a safety strategy perspective, involving information about the individuals in the data registration should be avoided. However, this can be tricky if there are ethical concerns.

Understanding why people do not follow the rules is risky; it becomes a conflict if this information is handled as negative prevention towards the individual. The SE indicated that there is no answer for this concern. One of the perceived risks in creating new communicative meetings to show risks and narratives of accidents is workers and site management not having time for them or not finding them valuable.

Another interviewee did not see any risks, only opportunities, e.g., a knowledge bank helping in planning in the early stages. The respondent also did not find ethical concerns since the focus of the reporting is on the accident. Even for accident-prone people, it is information that only the site manager or the safety engineer knows about and maybe take a private discussion with the individual.

Satisfaction with the reporting

It would be better if one reports in a more detailed, informative, and descriptive manner, so that even if someone not involved in the event can understand. If investigations do not arrive at causes and prevention measures, then extracted conclusions cannot be made. One SE indicated dissatisfaction because much more could have been reported – reporting rates differ from site to site. Maybe site management did not want to catch attention, which causes reporting rates to drop – even though there are many more reports now; 1000 in one division while, some years ago, there were only 27.

As SEs support production and work with the portal, most of the reporting is done by site managers, site supervisors and maybe safety representatives. Many questions are very relevant for them, and they have another perspective of reporting and using the software.

Success criteria for a prototype based on the reports' data

From the strategist's point of view, having the workers on board is the most important thing – maybe not every single worker, but at least a small group that had already tried a new tool and given feedback. Introducing new things in the construction industry is not very popular, and that is a risk but also a kind of attitude. Therefore, management needs to promote and try the new tools themselves and engage in communication.

COMPARATIVE DISCUSSION THAT CAPTURES THE CONCEPTUAL AND EMPIRICAL COMPARISON

The business objective includes defining the client's goal and deciding on the objective or subjective success criteria from a business point of view – or, according to RP (DVN GL AS 2020), a value proposition that defines users and use-cases. Based on the interviews, the safety strategist was chiefly interested in behaviour and fatal accidents, while the SEs' propositions included the planning of work tasks and prevention, communication, and behaviour. Moreover, one of the SEs defined acceptance criteria for a new digital application, namely practicality, functionality connected to activities, and giving the feeling of added value to users.

The first direct difference between CRISP-DM's concepts and the empirical context can be summarized as singular versus multiple-goal orientation. CRISP-DM and RP encourage the data analyst to look for and specify a single business objective and client goal, whereas the contractor's diversification on different products, different organizational levels, and the project-based organisation exhibits multiple goals and objectives. Notably, the project's typical goal constellation would involve costs, time, and quality as prime objectives, whereas H&S and prevention of occupational accidents might be present but still play a minor role. The latter setting introduced ambiguity into the objectives of using a ML model and has to be embedded into "goal contradictions" rather than just a single goal. At the end of the first step of the business understanding, there is probably a need for iteration to sum up objectives and re-evaluate to make decisions on a common objective. The CRISP-DM guideline of deciding on the objective or subjective success criteria from the business point of view of the ML model assumes the active participation of the managers and employees in the development of the ML model, which is a feature our project does not encompass.

The second step of business understanding requires a detailed analysis of the related resources, constraints, assumptions to the business objectives, risks of project failure, terminology, and cost-benefit analysis from a commercial perspective. The recommendation of this stage is related to the resources of the H&S organisation, its members and most importantly, the data. There are resources to a certain level, but a detailed analysis of accident causes is rare. It is the corporate registration system that sets the limits for the effort. The constraints of the prevention activity are due to the business objectives of production, where time and cost own prevalence. Moreover, assumptions in the field of accident prevention are related to several different safety cultures in the project organisation (Koch 2013). At least two competing assumptions prevail in the interviews: first, that accidents are due to human error and therefore should be prevented by campaigns and other behaviour-oriented efforts, and second, that accidents can be prevented when systemically analysing the risks and making barriers for their impact. Furthermore, the interviewees showed conflicting views about risks associated with the latter prevailing safety assumptions. To sum up, analysts can extract information related to assumptions, practices, and data validity constraints. However, more requirements at this step seem challenging to define (such as the application design and ethical concerns), especially since most requirements need a vivid project and commercial benefits.

The following step would be defining data-driven goals. At this stage, there must be a clear definition of the prediction target and an agreement about the model's acceptable accuracy in achieving such a target. Based on the interviews and the latter analysis, the goal and constraints need to be defined beforehand. The many projects, product types, management levels, and other factors, make the context challenging to handle, and such liability and weakly defined phenomena make applying ML difficult. Moreover, the data status might not allow for a clear definition of the prediction target. Another iteration could be proposed to overcome this difficulty. If the situation assessment step had required a primary data analysis (besides listing detailed available data resources), it might be easier for the analyst and the case company to make the connection to concrete targets.

One of the preconditions for a ML application is to make a critical difference in prevention work, i.e., that the system compiles a large amount of data and analyses it in an overview not offered in previous methods, practices, and systems. In this occupational accident context, this means coupling many building projects and units across time and space. The SEs function similarly across many project contexts, so their active use of a standard ML system might provide an additional critical contribution



to prevention. The similar concerns and goals across time and space, rather than just the compiled database, create the critical mass for the system. It is likely that even other datasets in the contractor's system (e.g., quality data, production planning, and execution data) share this feature – a coexistence of a common database spread in space and time, but with similar goals.

The previous analysis shows that much can be uncovered by asking domain experts about daily processes and experiences. However, to define business understanding goals and expectations of data-driven (ML) applications requires working on multiple organizational levels, especially in project-based organizations. Adding an iterative step between the business understanding subtasks seems beneficial – otherwise, ethical, application design and data-driven goals, would remain ambiguous. Moreover, the current description of business understanding seems to target commercial gains at a strategic decision-making level. In contrast, in a large contracting company and on the operational level, the business understanding framework needs to and can be adapted to match the specific case.

CONCLUSIONS

This paper aimed at analysing experiences and challenges in using the “business understanding” phase of CRISP-DM; and as part of an ongoing endeavour to develop a ML-based system that utilises reported accidents for prevention. The interest in “business understanding” stems from intending to assure a solid contextual embedding and an appreciation of local dynamics (incl. variations in roles, competencies, and resources). Our sociomaterial framework of understanding was supplemented with accident research and ML development concepts, and the complex context of a contractor company was elected. Due to the contractor's differentiation in business units and areas and its project-based production, it can be (as the interviews also showed) compared to a loose constellation of many small companies. Therefore, the method adopted was a bottom-up approach.

The paper's first result evaluates CRISP-DM's “business understanding” as too general to provide sufficient guidelines for ML development. There are relevant questions to be asked in the company context, such as the goal for the business and the application domain, but little support can be found for more particular decisions on the ML system design. We, therefore, shifted from a top-down to a bottom-up approach, where the iterative system development drew directly on practical experience and knowledge on accident registration procedures and registered accidents. The second result was the difficulties in understanding registered data in the standard database software, with limited transparency and different quality – complementing other research on the importance of the reporters' interpretation. The third result is appreciating the classical decoupling between top management and the building project level in Swedish contractor companies. This hampers the integration of accident prevention in the operational level. ML systems should be designed to provide the coexistence of a common database and user experience spread in space and time, but with similar goals in large contractor organisations with many projects and job functions. The review of the “business understanding” in this case showed the need for two iterations within the process; one at the “determine business objective” step to agree on common goals, and the second at the “assess situation” stage to include primary data analysis for realistic data modelling goals and definitions.

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BARRIERS TO INDUSTRY 4.0 TECHNOLOGY INTEGRATION IN CONSTRUCTION HEALTH AND SAFETY (H&S) MANAGEMENT IN ZIMBABWE

Benviolent Chigara, John Smallwood

Nelson Mandela University, South Africa

Correspondence: john.smallwood@mandela.ac.za

Abstract

The integration of Industry 4.0 enabled technologies in construction health and safety (H&S) management is of paramount importance to improve workers' health, safety, and wellbeing. The COVID-19 pandemic expanded the need for Industry 4.0 technology integration in H&S management. Despite this, the findings of previous studies and anecdotal evidence indicate that the construction sector lags other sectors in terms of technology adoption. This study aims to identify the level of Industry 4.0 technology integration in construction H&S, and the factors affecting the integration of Industry 4.0 technologies in construction H&S management. A quantitative survey design was adopted which entailed the distribution of questionnaires to architects, construction managers, engineers, and quantity surveyors, in construction and consultant firms in Harare. The data analysis consisted of computing frequencies and a measure of central tendency in the form of mean scores (MSs) to facilitate ranking of the factors. The results of the study indicate that Industry 4.0 technologies integration in H&S management is sub-optimal. The high investment cost, lack of knowledge of emerging technologies, lack of client support, lack of awareness relative to technologies necessary for H&S, and lack of top management support are the leading factors limiting the integration of technology in H&S management. The study results highlight the significance of policies and strategies that aim to reduce the cost, and raise awareness of H&S technologies in terms of promoting an Industry 4.0 technology-led H&S performance improvement drive. Although the study was exploratory, the findings are useful to inform construction stakeholders with regards to areas that require interventions to enhance technology integration in construction H&S management.

Keywords: construction, health and safety, Industry 4.0, Zimbabwe.

INTRODUCTION

The construction sector is considered as a hazardous work-sector due to its disproportionate contribution to occupational injuries. According to the International Labour Organisation (ILO) (2015), approximately 108 000 fatalities are recorded on construction sites each year globally. In Zimbabwe, statistics courtesy of the National Social Security Authority (NSSA), show that the incidence rate (IR) of the construction sector exceeds the all-sector average. However, the economic and social burden of workplace injuries is enormous. The ILO (2015) estimates that approximately 4% of global Gross Domestic Product (GDP) is lost annually due to occupational injuries, fatalities, and disease. According to Chigara and Smallwood (2019), occupational injuries diminish the capacity of workers to meet their current and future work requirements. Against this background, the need to adopt innovative solutions to prevent/reduce occupational injuries in the construction sector cannot be overstated. In today's world, Industry 4.0, and its associated technologies emerged as an effective approach to improve and sustain site workers' H&S conditions (Haupt *et al.*, 2020; Mihić *et al.*, 2019; Oesterreich and Teuteberg, 2016; Okpala *et al.*, 2020; Smallwood *et al.*, 2020). The last two decades witnessed a growing interest in utilising innovative technologies to prevent / reduce workplace injuries and fatalities in the construction sector (Ramos, 2021; Nnaji *et al.*, 2020) due to their great potential to



enhance H&S performance (Aslan, 2019; Liu *et al.*, 2020; Romero *et al.*, 2018; Nnaji and Karakhan, 2020).

Nnaji and Karakhan (2020) note that several Industry 4.0 technologies have been applied in H&S management in the United States of America (USA), albeit at various stages. The study showed that most of the respondents (86%) were exposed to / used Building Information Modelling (BIM), wearable sensing devices (WSDs), and radio-frequency distribution (RFID) as part of their H&S management process; while 58% revealed that their organisation used Unmanned Aerial Vehicles (UAVs), augmented reality (AR), virtual reality (VR), robotics, and automation to improve H&S performance (Nnaji and Karakhan, 2020). During another study conducted in South Africa, Beale and Smallwood (2019) determined that Industry 4.0 technologies such as VR, AR, VR based H&S training, drone technology, and wearable technology / sensors are perceived to have great potential to contribute to resolving many H&S challenges experienced in the construction sector. According to the Health and Safety Executive (HSE) (2018), applying BIM during the planning and design phase enables site layout and logistics planning, and early (design) hazard identification and mitigation before physical work begins. The use of sensors and global positioning system (GPS) enhances collision detection, exposure assessment, detection of unsafe construction site location (Häikiö *et al.*, 2020; Howard, 2017) thereby reducing / preventing accident involving heavy equipment and workers-on-foot (Genders *et al.*, 2016). Internet of Things (IoTs) and its accompanying technologies (sensors) can enable real-time monitoring of workers and their operating / surrounding environment relative to hazards, unsafe acts (UA) and unsafe conditions (UC); real time provision of information necessary for real-time decision making relative to H&S (Dapan *et al.*, 2019; Häikiö *et al.*, 2020) and timely hazard evaluation (Erol and Kecioren, 2019).

Despite the potential benefits of Industry 4.0 technologies for H&S, the technologies are not broadly applied in construction H&S management (Okpala *et al.*, 2020; Nnaji and Karakhan, 2020; Ramos, 2021; Swallow and Zulu, 2019). Further, research investigating the barriers to Industry 4.0 technology integration in H&S management remains limited, and there is no evidence of any such study having been conducted in Zimbabwe. To bridge this gap, this study investigates the perceptions of construction professionals in Harare with regards to the barriers to Industry 4.0 technology integration in construction H&S management in Zimbabwe. Through identifying the barriers to integrating Industry 4.0 technologies in H&S management, the study provides important insights to construction stakeholders regarding interventions required to enhance the integration to improve construction H&S performance.

REVIEW OF RELATED LITERATURE

This section discusses the state of construction H&S in Zimbabwe and barriers to technology integration in construction H&S management.

Overview of the status of construction H&S in Zimbabwe

The construction industry's H&S record is undesirable. Studies conducted in Zimbabwe reveal that the organisation and implementation of construction H&S is poor (Moyo *et al.*, 2015; Chipato *et al.*, 2019). This is corroborated by the NSSA H&S statistics for the period 2011 to 2015, which shows that the average incidence rate (IR) (6.0 per 1 000 insured workers) for the construction sector is above the all-sector average IR (5.2 per 1000 insured workers) (NSSA, 2017). The leading types of accidents contributing to non-fatal injuries are: contact with objects (28%); fall of objects (14.4%); fall of persons (13.9%); overexertion when lifting, pushing, or pulling heavy objects (10.7%); road traffic accidents (9.78%), and caught in or between objects (8.68%) (NSSA, 2015). The factors contributing to the poor construction H&S performance are non-compliance with H&S provisions (NSSA, 2015), unsafe work practices, inadequate inspections, inadequate hazard identification and risk assessment (HIRA), inadequate H&S planning, inadequate H&S training, and inadequate design HIRA, which contribute to the occurrence of injuries, fatalities, and disease (Chigara, 2018). This calls for more action to improve the situation. Previous studies (Okpala *et al.*, 2020; Liu *et al.*, 2020) determined that emerging Industry

4.0 technologies, when used appropriately have the potential to enhance construction H&S. Nonetheless, several factors / barriers limit the application of these technologies in H&S management.

Barriers to Industry 4.0 technology integration in construction H&S management

Swallow and Zulu (2019) investigated the barriers to adopting 4D modelling for site H&S in the United Kingdom (UK) using a questionnaire survey administered to construction practitioners. The results showed that only 31.2% of the participants had adopted 4D modelling in their workplace, and that the main barriers limiting the adoption of 4D modelling for H&S are the cost to train, culture, cost of software, time to implement, no collaboration, and lack of information technology (IT) skills. During another study conducted in the USA, Nnaji and Karakhan (2020) established that the top five barriers limiting the adoption of innovative technologies for H&S management are expensive upfront cost, need for extensive training before achieving optimum performance, concerns regarding the technical support availability, doubts regarding reliability of these technologies, and clients rarely demand for their use. Schall *et al.* (2018) adopted a survey design to investigate the potential barriers preventing the widespread adoption of wearable sensors in the construction industry based on the perceptions of the members of the American Society of Safety Engineers. The results of this study showed that the barriers preventing the adoption of wearables in construction H&S are the concerns regarding employee privacy / confidentiality of collected data, sensor durability, and the benefit / cost ratio of using wearables. Kim *et al.* (2019) investigated the perceptions of 26 construction industry representatives in the states of Virginia and California, USA, regarding their opinion and concerns with respect to the use of exoskeleton technology in construction to enhance H&S management. The perceived barriers to the adoption of exoskeletons are the H&S concerns (of the workers using them) and usability concerns. During another study, Borhani (2016) established that cost, complexity to use, uncertainty in terms of obtaining benefits, time needed to learn and adopt the tool, and the need for additional training are the main barriers affecting the adoption of technology for construction H&S in the USA. Azhar and Behringer (2013) investigated the effectiveness of BIM technologies in developing, communicating, and implementing H&S plans in the USA. The study established that the lack of knowledge of H&S personnel in terms of using BIM, technical issues such as non-availability of H&S elements and equipment in the BIM software library, and human behaviour, which cannot be changed quickly, as the main challenges related to the use of BIM for H&S management. Table 1 presents an overview of factors / barriers constraining Industry 4.0 technologies integration in H&S management.

Table 1: Overview: barriers to Industry 4.0 technologies integration in construction H&S management

Location	Reference	Identified barrier
UK	Swallow and Zulu, 2019	The cost to train, culture, cost of software, time to implement, no collaboration, and lack of information technology (IT) skills.
USA	Borhani (2016)	Cost, complexity to use, uncertainty in terms of benefits, time needed to learn and adopt the tool, and the need for additional training.
USA	Nnaji and Karakhan, 2020	Expensive upfront cost, need for extensive training before achieving optimum performance, concerns regarding the technical support availability, doubts regarding reliability of these technologies, and clients rarely demand for their use.
USA	Schall <i>et al.</i> (2018)	Employee privacy / confidentiality of collected data, sensor durability, and the benefit / cost ratio of using wearables.
USA	Azhar and Behringer (2013)	Extra cost involved in developing the BIM-based H&S plans, lack of knowledge of H&S personnel in terms of using BIM, technical issues such as non-availability of H&S elements and equipment in the BIM software library, and human behaviour which cannot be changed quickly.

The review of literature provides important insights with regards to the barriers to adopting Industry 4.0 technologies in H&S management. However, the review of literature reveals that available research with respect to the subject is limited and geographically biased towards the developed



regions, and then mainly the USA. This calls for further studies to be conducted in other geographical locations. Although related studies were conducted in South Africa, they focus on the applicable Industry 4.0 technologies for H&S management (Haupt *et al.*, 2020), the level of integration, and the benefits of Industry 4.0 technologies in H&S management (Smallwood *et al.*, 2020; Beale and Smallwood, 2019).

RESEARCH METHOD AND SAMPLE STRATUM

Research design

The study adopted a quantitative approach which entailed the distribution of questionnaires per emails to construction professionals, namely architects, construction managers, construction H&S managers / officers, engineers, project managers, and quantity surveyors from contractors and consultant firms in Harare. An exploratory survey research design was adopted because survey design is an established research design in construction management research (Dainty, 2008) capable of providing a quantitative description of attitudes and opinions of a population or tests of association among variables of a population, by studying a sample of that population (Creswell and Creswell, 2018). The study conducted in Harare, the capital city of Zimbabwe because the city hosts the largest pool of construction professionals in Zimbabwe.

Questionnaire design and administration

A structured questionnaire, accompanied by a covering letter explaining the rational of the study, procedures for completing the survey, a request for participation in the survey, and assurances of confidentiality, was used to collect data from construction professionals. The questionnaire comprised eight close-end questions. Six (6) questions sought to obtain the socio-demographic data of the respondents such as age group, gender, education, job title / designation, organisation, and years of work experience in the construction industry. Two questions sought to obtain respondents' perceptions relative to (1) the extent to which Industry 4.0 technologies (BIM, RFID, UAVs, VR, AR, robotics, drone technology, automation, IoTs, additive manufacturing (AM), and mobile computing) are applied to eight (8) aspects of construction practice, and (2) the extent to which twenty-three (23) barriers selected from literature hinder Industry 4.0 technologies integration in construction H&S management in Zimbabwe. A five-point Likert type scale ranging from 1 = Not at all, 2 = Minor, 3 = Moderate, 4 = Near major, and 5 = Major extent was applied to determine respondents' perceptions with respect to the above questions. Prior to distributing the questionnaire, three construction professionals / experts, selected based on their theoretical questionnaire knowledge (DeMaio and Landreth, 2004) and practical construction H&S management experience, were asked to review the questionnaire in terms of potential questions and the adequacy of the factors included in the questionnaire. The revised questionnaire, incorporating experts' feedback, was then distributed to forty-five (45) purposively selected construction professionals in Harare. As the study is exploratory, purposive sampling was used to select the professionals based on their experience / involvement in construction H&S management and exposure to / use / knowledge of Industry 4.0 technologies.

Data analysis

The data was analysed with the help of the Statistical Package for Social Scientists (SPSS) software to compute frequencies, and a measure of central tendency in the form of a MS to facilitate the interpretation of percentage responses to Likert scale type questions, and the ranking of the variable. The MSs were interpreted in line with previous studies (Smallwood, 2020) where: MS ' $\geq 1.00 \leq 1.80$ ' = minor to near minor extent; ' $> 1.80 \leq 2.60$ ' = minor to a near minor / near minor extent; ' $> 2.60 \leq 3.40$ ' = near minor to a moderate / moderate extent'; ' $> 3.40 \leq 4.20$ ' = moderate to near major / near major extent, and ' $> 4.20 \leq 5.00$ ' = near major to major / major extent. As suggested by Ikediashi *et al.* (2012), a midpoint score / benchmark of 3.00 $[(1+2+3+4+5)/5 = 3]$ was used to identify significant barriers. The barriers with MSs > 3.00 are considered significant (Ikediashi *et al.*, 2012). Where two or

more factors had the same MSs, the standard deviation was used to facilitate rank differentiation (Doloi *et al.*, 2012). Due to the small sample, inferential statistical analysis was not feasible.

RESEARCH FINDINGS

Response rate

A total of 45 questionnaires were emailed to construction professionals and 21 responses were received, representing a response rate of 46.7%. Due to the small sample, the results may be regarded as indicative. However, such responses are likely to have been obtained from the more committed practitioners, and practitioners that are familiar with and / or have an interest in the subject area, thereby reinforcing the validity of the findings (Smallwood, 2019). Notably, small samples have previously been reported in construction management research. During a related study in Malaysia, Yong and Mustaffa (2012) distributed 45 questionnaires to different target groups in the construction industry and 14 responses, representing a response rate of 31.1%, were received and analysed.

Demographic profile of respondents

In terms of the demographic profile, 90.5% of the respondents were males, while females constituted 9.5%. The huge gender disparity confirms the results of the ZimStat (2019) survey which showed that females make up 11.8% of wage / paid employment in the non-agricultural sector. With regards to the age groups, the results show that most respondents (85.7%) comprise of Generation Y (1982 – 1994) followed by Generation X (1965-1981) age group (14.3%). The respondents' level of education comprised Bachelor's degree (76.2%), Master's degree (9.5%), Diploma (9.5%), and other (4.8%). In terms of the organisation represented by the respondents, 57.1% are construction consultants and 42.9% contractors. The analysis shows that most of the respondents are quantity surveyors (38.1%), followed by project managers (19.0%), engineers (14.3%), construction managers (14.3%), architects (9.5%), and H&S managers (4.3%). Regarding the respondents' years of work experience in the construction sector, the analysis shows that 38.1% of the respondents have 6-10 years of work experience followed by the 0-5 years category (28.6%), 11-15 years (23.8%), and 16 years and over (9.5%). The diverse backgrounds and experience of professionals who responded to the survey enhances the relevance of the responses.

Application of Industry 4.0 enabled technologies in the construction industry in Zimbabwe

Table 2 presents the results of an assessment of the extent to which Industry 4.0 technologies are applied to construction industry practices in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

Table 2: Extent to which Industry 4.0 technologies are applied to eight construction industry practices

Practice	Response (%)						MS	Std. dev.	Rank
	Un-sure	Not at all..... Major							
		1	2	3	4	5			
Cost management	0.0	0.0	9.5	33.3	42.9	14.3	3.62	0.865	1
Project schedule management	0.0	4.8	14.3	42.9	23.8	14.3	3.29	1.056	2
Construction site management	0.0	9.5	33.3	14.3	23.8	19.0	3.10	1.338	3
Resources and asset management	0.0	4.8	38.1	47.6	4.8	4.8	2.67	0.856	4
H&S management	0.0	4.8	52.4	19.0	19.0	4.8	2.67	1.017	5
Productivity management	9.5	9.5	33.3	28.6	14.3	4.8	2.43	1.287	6
Quality management	0.0	23.8	33.3	33.3	9.5	0.00	2.29	0.956	7
Environmental management	9.5	19.0	38.1	19.0	14.3	0.00	2.10	1.179	8

It is notable that 3 / 8 (37.5%) of the MSs are > 3.00, which indicates that the respondents deem that the Industry 4.0 technologies are applied to a major, as opposed to minor extent to 'cost management', 'project schedule management', and 'site management'.

The four construction practices ranked 1st to 5th (62.5%) have MSs > 2.60 ≤ 3.40, which indicates that the respondents deem that the Industry 4.0 enabled technologies are applied between a minor to a moderate / moderate extent to the selected practices - 'cost management', 'project schedule management', 'site management', 'H&S management', and 'resources management'. The construction practices ranked 6th to 8th (37.5%) have MSs > 1.80 ≤ 2.60, which indicates that respondents deem that the technologies are applied to 'productivity management', 'quality management', and 'environmental management' between not at all to a minor / minor extent. Overall, the results show that the application of Industry 4.0 technologies in construction industry practices is gradual and at various levels of maturity. The results confirm previous studies, which show that Industry 4.0 technologies have not gained much attention in construction despite the benefits of increasing automation and digitisation in construction processes (Oesterreich and Teuteberg, 2016).

Barriers to Industry 4.0 technologies integration in H&S management in Zimbabwe

Table 3 presents the respondents' perceptions relative to barriers inhibiting the integration of Industry 4.0 technologies in construction H&S management in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

Table 3: Barriers to Industry 4.0 technologies integration in construction H&S management in Zimbabwe

Barrier	Response (%)						MS	Std. dev.	Rank
	Un-sure	Not at all..... Major							
		1	2	3	4	5			
High investment costs	0.0	0.0	0.0	4.8	33.3	61.9	4.57	.598	1
Lack of knowledge of the technologies and their applications	0.0	0.0	9.5	9.5	28.6	52.4	4.24	.995	2
Lack of support from clients	0.0	4.8	0.0	19.0	33.3	42.9	4.10	1.044	3
Lack of awareness of the innovative technologies for H&S management	0.0	4.8	4.8	14.3	38.1	38.1	4.00	1.095	4
Lack of senior management support	4.8	4.8	14.3	14.3	47.6	28.6	3.90	1.044	5
Inadequate technology integration in built environment programmes	0.0	0.0	9.5	19.0	47.6	23.8	3.86	.910	6
Lack of supportive government policy	9.5	0.0	0.0	19.0	33.3	38.1	3.81	1.470	7
Lack of technical expertise & experience	0.0	0.0	9.5	33.3	33.3	23.8	3.71	.956	8
Lack of information regarding the effectiveness of the technologies	4.8	0.0	4.8	33.3	23.8	33.3	3.71	1.271	9
Lack of a supportive regulatory framework	9.5	0.0	9.5	4.8	42.9	33.3	3.71	1.521	10
Resistance to [technology] change	0.0	4.8	19.0	9.5	42.9	23.8	3.62	1.203	11
Inadequate / Weak [ICTS] infrastructure	0.0	0.0	23.8	23.8	23.8	28.6	3.57	1.165	12
Lack of industry standards to guide implementation	0.0	4.8	9.5	33.3	33.3	19.0	3.52	1.078	13
Lack of training	0.0	0.0	14.3	33.3	42.9	9.5	3.48	.873	14
Lack of clearly defined economic benefits (Uncertain ROI)	0.0	4.8	19.0	23.8	28.6	23.8	3.48	1.209	15



Lack of demand from contractors	4.8	4.8	4.8	33.3	28.6	23.8	3.48	1.327	16
Lack of requisite Information Technology (IT) skills	0.0	4.8	19.0	38.1	23.8	14.3	3.24	1.091	17
Lack of a methodical strategy for implementation	4.8	0.0	19.0	23.8	47.6	4.8	3.24	1.134	18
Lack of technical support from technology providers	4.8	4.8	19.0	19.0	42.9	9.5	3.19	1.290	19
Economic risk	4.8	4.8	9.5	47.6	14.3	19.0	3.19	1.289	20
Perceived technology interference with work procedure	0.0	4.8	28.6	28.6	28.6	9.5	3.10	1.091	21=
Unsupportive organisational structure	0.0	9.5	19.0	28.6	38.1	4.8	3.10	1.091	21=
Industry culture that promotes slow technology adoption	0.0	9.5	19.0	28.6	42.9	0.0	3.05	1.024	23

Note: MS = Mean Score; Std. Dev. = standard deviation; ROI = return on investment

It is notable that all the MSs are greater than the midpoint score of 3.00, which indicates that respondents deem that the barriers constrain the integration of innovative technologies in H&S management to a major, as opposed to a minor extent. The variables ranked 1st and 2nd (8.7%) have MSs $> 4.20 \leq 5.00$, which indicates that respondents deem the barriers to constrain the integration of Industry 4.0 technologies in construction H&S management between a near major to a major / major extent. It is notable that 'high investment cost' is considered the leading barrier. Investment in Industry 4.0 technologies is perceived to be expensive because of the numerous cost centres such as the initial set-up cost, cost to train (Swallow and Zulu, 2019), cost of software / hardware / upgrades (Swallow and Zulu, 2019; Ahmed *et al.*, 2014) and running costs of the implementation (Ahmed *et al.*, 2014). This finding is consistent with previous studies conducted in the USA (Nnaji and Karakhan, 2020) and the UK (Swallow and Zulu, 2019) which identified the cost of investment as a leading barrier to the adoption of technology in H&S management. Given the high cost of investment, firms with a small financial muscle such as small to medium (SMEs) may find it more difficult to integrate technology in their H&S practices. The results show that 'lack of knowledge of the technologies and their applications' (MS = 4.24) is ranked 2nd. Knowledge of the innovative technologies is important to inform decision making relative to the application of the various technologies for H&S management. The lack of knowledge is identified in previous studies as a limiting factor for technology adoption in the construction sector in the USA (Holt *et al.*, 2015; Ahmed *et al.*, 2014). However, the gradual growth in technology use in the construction industry amplifies the need for construction enterprises and built environment institutions to impart knowledge to workers, managers, and students relative to the Industry 4.0 technologies that can enhance H&S management.

The fourteen barriers ranked 3rd to 16th (60.9%) have MSs $> 3.40 \leq 4.20$, which indicates that construction professionals perceive that the barriers constrain the integration of Industry 4.0 technologies in construction H&S management between a moderate to a near major / near major extent. The following section will briefly discuss three barriers in the top half of the above MS band (i.e., $> 3.80 \leq 4.20$). The effect of these barriers leans towards a near major impact, and hence are considered important in terms of influencing the decision to adopt innovative technologies. The barrier ranked 3rd is the 'lack of support from clients' (MS = 4.10). Given the high cost of investment with regards to the Industry 4.0 technologies, client support relative to technology integration is critical since they pay for the use of the technologies. This finding is consistent with Nnaji and Karakhan (2020) who established that lack of client involvement in the technology discourse impedes the integration of such technologies in H&S management. The finding reinforces the observation made by Lindblad and Guerrero (2020) that in project constellations, construction firms are much dependent on clients to allow for innovation. Although clients (large private and public) can potentially use procurement to influence technology integration in H&S management (Linderth, 2010; Lindblad and



Guerrero, 2020), the use of the lowest price as the dominant selection criterion in tenders discourages clients from exercising a leadership role to foster innovation (Loosemore and Richard, 2015). The respondents perceive that 'lack of awareness of the innovative technologies for H&S management' (MS = 4.00) is an important barrier to technology integration in H&S management. The lack of awareness may be attributed to the lack of integration of Industry 4.0 technologies in H&S management and the lack of exposure to the technologies. Previous studies show that construction H&S professionals rated themselves below average in terms of awareness of / exposure to most Industry 4.0 technologies (Beale and Smallwood, 2019; Smallwood *et al.*, 2020). In the UK, Swallow and Zulu (2019) established the low level of awareness of the 4D modelling contributed to the low adoption of 4D for H&S management. However, the lack awareness and understanding of the technologies in terms of their potential impact, and how they can be implemented within firms may discourage the uptake of Industry 4.0 technologies. At the organisational level, respondents perceive that adoption of innovative technologies in H&S management is affected by the 'lack of top management support' (MS = 3.90). Leadership support is required to set the vision for the adoption of Industry 4.0 technologies, allocate resources for the purchase of the required technologies, training, and retraining of workers and managers in line with the new technologies. Orzes *et al.* (2020) argue that lack of top management support is more important than employee resistance of technology. This finding is consistent with Borhani (2016) who identified lack of top management support as a major barrier limiting the adoption of technologies for H&S management. During this study, Borhani (2016) determined that while top management support may be forthcoming from large organisations because they have the resources, the situation is different for SMEs.

The seven barriers ranked 17th to 23rd (30.4%) have MSs $> 2.60 \leq 3.40$, which indicates that construction professionals perceive that the barriers to impede technology integration in H&S management between a minor to a moderate / moderate extent. The factors included in this cluster are: 'lack of requisite Information Technology (IT) skills'; 'lack of a methodical strategy for implementation'; 'lack of technical support from service providers'; 'economic risk'; 'perceived technology interference with work procedure'; 'unsupportive organisational structure', and 'industry culture that promotes slow technology adoption'. The results highlight the importance of developing a proper infrastructure, skilling, and reskilling in line with Industry 4.0, and culture shift to promote the adoption of technology-based solutions for H&S issues.

CONCLUSIONS AND RECOMMENDATIONS

The study investigated the perceptions of construction professionals in Harare to identify the level of Industry 4.0 technologies integration in construction practices, and the barriers to Industry 4.0 technologies integration in construction H&S management in Zimbabwe. The results of the study show that the level of Industry 4.0 technology integration in construction management practices and specifically H&S management is sub-optimal. The main barriers to technologies integration in H&S management are high investment cost, lack of knowledge, lack of client support, lack of awareness relative to the innovative technologies for H&S, lack of top management support, inadequate technology integration in built environment programmes, and lack of supportive government policy. The results highlight how deficiencies from various stakeholders such as government, contractors, training institutions, and clients impede Industry 4.0 technology integration in H&S management. The multi-dimensional nature of the barriers suggests that any transition towards Industry 4.0 technology-based solutions to H&S issues requires interventions at various levels. These results have some practical implications for policy and practice. First, the results highlight the centrality of the cost of investment on the decision to adopt innovative technologies for H&S management. Given that most of Industry 4.0 technologies are imported, the government should, in the short term, introduce policies (e.g., subsidies, and incentives) that promote economy in terms of start-up and implementation costs of the various technologies. Second, the lack of knowledge among construction stakeholders calls for higher education institutions (HEIs) to integrate innovative technologies into built environment programmes to close the knowledge gap and ensure that skills produced match



those required by the industry. Enterprise level training can also help to enhance knowledge and skills required to apply the technologies. Third, the absence of supportive policy and legal framework calls for the government to develop policies and regulations that promote technology adoption in construction and specifically for H&S management. The main limitation of the study is that it was conducted in one city in Zimbabwe, with a small sample of participants, which limits the generalisability of the findings to construction sectors in other regions.

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A BIM for safety Framework Involving Automated Rule Checking, Visualization and Training

Adeeb Sidani, João Poças Martins, Alfredo Soeiro

Faculty of Engineering, University of Porto, Portugal

Correspondence: adeeb.sidani@hotmail.com

Abstract

The construction industry bears a lot of casualties and accidents more than other high-risk industries annually. Thus, to have a practical site inspection, monitoring, and training, the AECO (Architecture, Engineering, Construction, and operation) is gradually integrating new digital technologies such as building information modelling (BIM), automatic rule checking, Augmented and Virtual Reality (AR/VR).

The current research objective is to provide a general framework of a BIM-based safety system to improve the safety status in the construction field. The system aims to offer Safety planning, Visualization, safety management, training, automated rule checking, monitoring and inspection. A BIM for Safety verification system is proposed, based on a fully automated approach, adopting Automated rule checking, and a manual approach adopting Virtual and Augmented Reality (AR/VR). These two systems will be a part of a BIM for Safety General Framework, which covers the construction project lifecycle with all the involved stakeholders and international standards.

The BIM-based technologies can help with safety prevention, inspection, monitoring, and training from the design stage to the operation and management. The integration of these tools in a standardised manner could ease the adoption of the tools, following EN ISO 19650-1 and PAS 1192-6:2018, giving the owner better awareness and control over the safety aspects of the project, identifying specific tasks for each stakeholder, and involving health and safety measures from the beginning of the project. Some limitations are found in implementing new tools since every tool represents a standalone, each tool covers a specific field only, the digital tools are not involved in the standards and regulations, workers and safety professionals lack the experience of using such tools, low demand from the owners, incompatibility of software and data format exchange, especially between different appointed parties, and the time spent preparing the BIM model.

Keywords. Building Information Modelling, Automated Rule Checking, Augmented Reality, Virtual Reality, Construction, Occupational Health and Safety.

Introduction

Construction safety is an international concern, with many injuries occurring in construction sites worldwide (Zhang, Teizer, Lee, Eastman, & Venugopal, 2013a). In line with the Occupational Safety and Health Administration (OSHA), the construction industry was responsible for 199,200 injuries and illnesses in 2019. According to the U.S. Bureau of Labour Statistics, construction had 9.5 fatalities per 100,000 full-time workers (U.S. Department of Labor; Bureau of Labor Statistics, 2019). According to OSHA, as of 2020, "one in five worker deaths in 2019 in construction".

Falls, struck-by-objects, electrocution, and stuck-in are considered the fatal four construction accidents and were responsible for more than half of the construction workers deaths at 58.6% in 2020 (U.S. Department of Labor; Bureau of Labor Statistics, 2019).

In a study conducted by Chim on the Causes and Preventive Approaches to Mitigate Accident Rate, Chim reassured that the company and the workers' negligence is the leading cause for accidents on



the construction site (Chim, Chun, & Wah, 2018). Chim mentioned that accidents could be avoided if the construction company management is careful with supervision during the construction process. According to Abdelhamid and Everett, three factors trigger accidents: not identifying a dangerous situation related to a specific task, ignoring a hazardous condition, and proceeding with the activity, or acting unsafe whatever the current environment was (Abdelhamid & Everett, 2000). In a book published by the Health and Safety Executive, the authors explored several points such as the influence of the human's behaviour on health and safety, the impact that health and safety problems have on the worker's physical and mental health, and the book also illustrates how to identify and solve these issues (Health and Safety Executive, 1999). This book states that a thoughtful understanding of human actions at work can reduce the number of accidents and cases of occupational hazards. Unsafe human on-site actions cause at least 80% of accidents since people are involved during the whole construction lifecycle. The authors divided the human factors into violations and errors that are further divided into skill-based errors and common mistakes (Health and Safety Executive, 1999).

Moreover, the causes of the issues are related to the organisation's planning, management and decision-making functions. The authors suggested having planned construction and maintenance tasks and an organized site environment with workplace precautions, risk control systems, and management arrangements to assist with safer construction works. In addition, the skills, capabilities and mental health of the individuals should be assessed for each task (Health and Safety Executive, 1999).

Thus, the construction site requires regular and advanced monitoring and supervision; besides, new workers must be trained carefully before going to the construction site to avoid unsafe actions. Consequently, manual monitoring and supervisions are prone to error due to the complex and dynamic environment. Subsequently, to assist the supervisors and visual inspection of the risks, automated safety monitoring such as Building Information Modelling (BIM) is adopted by the AECO sector (Eleftheriadis, Mumovic, & Greening, 2017). BIM integrates Building Regulations and health and safety information within the model that are specified as BIM4REGS task group. These groups have been developed by representatives from the AECO sectors, all with a common goal in developing and improving awareness, skill, and the use of BIM. The health and safety group aims to incorporate health and safety requirements into BIM so that users can immediately see whether their designs are compliant (Mordue & Finch, 2019). Therefore, BIM implementation seems promising and can also assist the continuous advancements in the construction processes. Furthermore, BIM can provide essential decision-support tools for engineers throughout the design stage, improving workers' safety and performance and enriching on-site and off-site training (Wang & Chong, 2015).

Digital Technologies for Construction Safety

BIM application in the AECO sector

BIM application in the AECO sector has several benefits, such as reducing health and safety challenges, improving the project's quality, and enhancing collaboration (Enshassi, Ayyash, & Choudhry, 2016). There is significant interest in improving safety through design and work method using BIM by implementing safety planning throughout the project (Enshassi et al., 2016). BIM enables workers, safety specialists and engineers to digitally visualise and monitor construction sites and identify hazards (Azhar, Khalfan, & Maqsood, 2012; Enshassi et al., 2016). Consequently, with the advancement of BIM and the lifecycle realisation of the project in one holistic environment, most of the Health and Safety information can be generated in this single environment (Kim, Jeong, Clayton, Haberl, & Yan, 2015; Schwegler, 2010). Furthermore, 4D-BIM, which is 3D models plus schedule, means improved chances to make alternative preliminary plans of different construction stages and tasks, linking them more to safety (Ganah & John, 2015).

The AECO sector is recognised for its increasing complexity and competitiveness due to strict schedules, complex tasks, and limited budgets, driving the search for automated and technological solutions (Chan, Scott, & Chan, 2004; Pham, Pedro, Le, Lee, & Park, 2017). Digitalisation has offered



this sector the means to pursue higher performance and accuracy, thus reducing costs and modernising operations. Implementing BIM methodology has benefited the AECO sector in collaboration, scheduling, 3D drawings, management, quantity, and material sorting. Consequently, various countries are adopting BIM. For European countries, BIM adoption is reinforced by Directive 2014/E.U., Article 22 (European Commission, 2014), which refer to BIM application for public procurement and by the modern international standard for BIM EN ISO 19650-1 (BS EN ISO 19650-1, 2018). The AECO sector is currently implementing several tools and methodologies to assist BIM, such as Automated Rule checking, Augmented Reality (AR), Virtual Reality (VR) (Sidani, Dinis, et al., 2021; Sidani, Matoseiro Dinis, et al., 2021).

Fully Automated Verification Systems (Rule Checking)

Rule-based checking systems have been developed for BIM models as part of the new BIM technology 3D and 4D simulations, which means a mockup of the geometric model (3D) and a geometric model with schedule details (4D), to improve the understanding of construction operation. These are some of the features embedded in BIM, allowing effective safety planning throughout the project's lifecycle (Eastman, Lee, Jeong, & Lee, 2009). In addition, such technologies can improve health and safety through automated risk identification at an earlier stage and propose inexpensive and straightforward ways to solve unsafe situations.

According to Sijie Zhang, collecting and examining construction data (work breakdown, structure, schedules, resource allocation) can be linked to a BIM model allowing to generate a rule-based health and safety framework that facilitates safer design, planning and execution of work tasks (Zhang, Teizer, Lee, Eastman, & Venugopal, 2013b). In addition, joining the construction data with safety rules, such as OSHA, and geometric project data can create information that, once the database is linked to the BIM model, will create knowledge that can enhance safety education and training at the design and construction stage (Zhang et al., 2013b).

Safety standards and codes represent guidelines for construction risk identification. Therefore, it is convenient to link BIM components or activities with relevant safety regulations and codes to carry out automatic risk identification. According to Guo Hongling (Hongling, Yantao, Weisheng, & Yan, 2016a), a safety rule system is thus built by:

- Categorising construction safety information,
- Building a safety rule system
- Translating safety rule system to machine-readable language.

Various kinds of standards may classify unsafe design factors from distinct perceptions and describe the same rule in a changed structure; that is, rules and standards are not organized and standardized for automated rule checking. Therefore, reorganising the rules with a specific format and facilitating rule checking is required (Hongling et al., 2016a). However, all these standards can be classified into safety protection, design computation and design checking. Furthermore, as the rules are used to prevent accidents, the design safety-related information is updated according to accident-related data. Thus, an organised and well-structured safety rule system can be developed (Hongling et al., 2016a).

Several studies developed automated rule checking systems targeting falling (Hongling, Yantao, Weisheng, & Yan, 2016b; Hossain & Ahmed, 2019; Malekitabar, Hassan Ardeshir, Abdollah Sebt, Mohammad Hassan Stouffs, 2016; Zhang, Sijie Sulankivi, Kristiina Kiviniemi, Markku Romo, Ilkka Eastman, Charles M. Teizer, 2015; Zhang et al., 2013b) which are the most common risk to target using automated rule checking. However, many hazards are too complex and interrelated to be automated such as handling equipment and heavy machinery, installations, material control, among others. These kinds of risks are becoming more common to be integrated in automated rule checking (Malekitabar, Hassan Ardeshir, Abdollah Sebt, Mohammad Hassan Stouffs, 2016), but a fully manual approach might be easier to implement while taking advantage of current technologies.



Fully Manual Verification systems

Augmented Reality

"Augmented Reality (AR) is a live view of computer-generated information or image augmenting or laying over the real-world environment" (Vincent, 2012). BIM-based AR advancements within the AECO sector, providing an array of applications. Azuma describes AR as a variation of VR, which provides a natural environment with the incorporation of virtual objects (Azuma, 1997).

Chi and Wang verified that AR technology evolved from marker-based applications towards markerless systems, only uses sensors in the environment to calculate the position and orientation of the camera and does not require prior knowledge of the environment to overlay virtual 3D content into a scene and hold it to a fixed point in space (Chi, Kang, & Wang, 2013). However, recent advances in context-aware tools such as Wikitude, Google's Project Tango, ARCore and ARKit, may expedite the technology used on mobile devices, given the increasing processing capabilities of portable devices (Sidani, Matoseiro Dinis, et al., 2021). Additionally, Data Cloud computing environments have been recognised in server-based applications and a wide variety of applied localisation technologies, dependent on the specifics of the system and the application or task itself. Simultaneously, the potential of gesture-based interfaces and HMDs (Head Mounted Display) were also reported (e.g., applications based on Microsoft HoloLens). BIM authoring tools such as Revit and ArchiCAD and game engines (e.g., Unity) support data transfer and the development of virtual environments (Sidani, Matoseiro Dinis, et al., 2021).

AR is primarily implemented in construction sites due to the visualisation and information extraction capabilities that it can provide. BIM-based AR applied to the construction site to support task completion and reduce construction errors, lower cognitive workload, improve access to project information, manage construction schedules and costs, improve collaboration, increase site assistance, safety training, task orientation, and higher productivity (Bae, Golparvar-Fard, & White, 2013; Jiao, Zhang, Li, Wang, & Yang, 2013; Park, Lee, Kwon, & Wang, 2013; Pour Rahimian, Chavdarova, Oliver, & Chamo, 2019). Specifically, for Architecture and Civil Engineering, AR may reduce construction errors and project design review; improved communication compared to more traditional 2D approaches, time-savings (working hours) and cost reduction, as defined by Agarwal (Charef, Alaka, & Emmitt, 2018). [Figure 1](#) demonstrates a step-by-step framework to develop an effective AR system for the AECO sector. The framework proposes is based on a holistic approach for integrating AR into the construction. Besides, providing AECO actors with an improved understanding of the technology's potential and suitability to overcome some industry barriers. The framework maps the relationship between AR capabilities and potential benefits based on 23 use cases. Furthermore, the relevance of conducting field tests should not be disregarded from AR implementation, as such an approach may ascertain improved user-friendliness and may also contribute to fostering acceptance and long-term usage (Berkemeier, Zobel, Werning, Ickerott, & Thomas, 2019). A compromise must be attained between the development team's know-how, state-of-the-art technology to the extent that possible difficulties in developing the solution can be minimised, and cost and economic aspects.

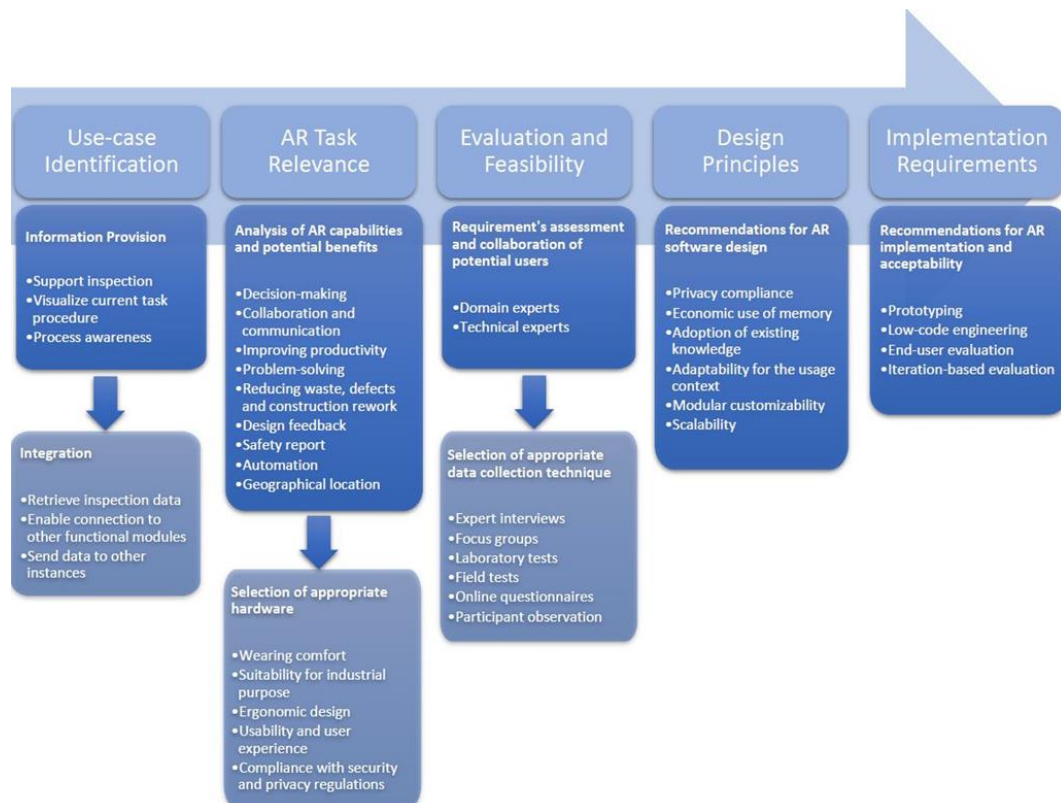


Figure 1 Framework for a Guided Integration of AR in the AECO Sector based on (Berkemeier et al., 2019; Hala, Christian, Makram, & Harald, 2020; Sidani, Matoseiro Dinis, et al., 2021; Steffen, Gaskin, Meservy, Jenkins, & Wolman, 2019)

Virtual Reality

VR has shown encouraging developments as technology prices become accessible to the general consumer and computational power increases (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017). In the last few years, VR research has focused on the AECO sectors, showing potential benefits in a plethora of applications, especially when taking advantage of accuracy and information comprised in BIM models (Li, Wu et al. 2017). Thus, BIM-based VR applications have shown many advantages to enhance design review, team collaboration, decision making, among others. The core idea behind VR application is to enable collaboration and communication, allowing people with different expertise to access BIM information (Sidani, Dinis, et al., 2021).

Kumar and hare presented an investigation that showed that the site experience is crucial for designers, and it is being reduced in the education curriculums (Hayne, Kumar, & Hare, 2017). Moreover, inexperienced designers do not recognise the impact they can make on on-site safety. Following the author's hazard perception test, an association between identifying and mitigating hazards and possession of site experience was found. The authors recommend that future studies should be undertaken to target educational technologies. VR could offer opportunities to develop solutions that could utilise the parametric attributes and assist with the education and training of designer and new workers (Hayne et al., 2017).

Most BIM-based VR tools utilise a three-layer system architecture comprising a BIM authoring tool, a game engine, and a visual enhancement module. Moreover, some studies expand to a fourth layer, database, to exchange non-geometric information (Sidani, Dinis, et al., 2021). It was also identified that other middleware applications were used to provide network connectivity, creating a multiuser immersive experience; Construction Safety – field focussed on improving the construction site safety, mainly through increased awareness and design simulation (Sidani, Dinis, et al., 2021). [Figure 2](#) illustrates an implementation framework of BIM-based VR.

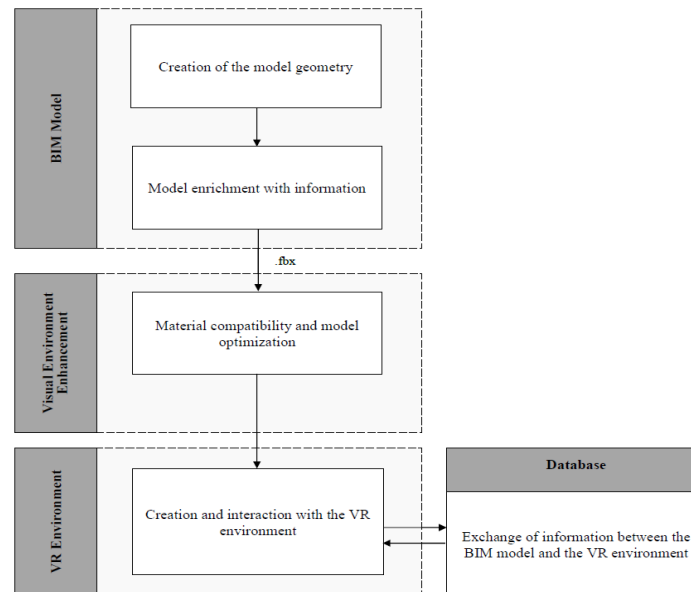


Figure 2 BIM-Based VR Development Framework

Proposed framework

Framework Description

The proposed BIM for Safety framework [Figure 3](#) combines the mentioned technologies generating a BIM for Safety Verification System. This system can be divided into Fully manual or Fully Automated approaches [Figure 4](#). Zhai mentioned that three aspects need to be improved to elevate the levels of health and safety and reduce risks: detecting hazardous areas at a specific time, monitoring and inspection, and training (Zhai, Goodrum, Haas, & Caldas, 2009). the current models are standalone models, either targeting visualization, automated rule checking, or safety management, safety planning but there is no framework combining these methods together and targeting most of the project life cycle and the target group. In addition, this system will be based on European regulations and standards which is mostly missing with the current systems.

Afterwards, the suggested BIM for Safety general framework [Figure 3](#) will be based on the established construction principles, such as EN ISO 19650 1 standard, an international benchmark for operating data over the project's life cycle using BIM. It includes principles and high-level requirements as United Kingdom government's BIM level 2 and is aligned with UK 1192 standards (Panteli et al., 2020).

Furthermore, integrating PAS 1192-6:2018 "Specification for collaborative sharing and use of structured Safety information using BIM". PAS 1192-6:2018 specifies requirements for the cooperative sharing of structured health and safety information throughout the project's life cycles. Supporting the development of structured health and safety data for construction projects gradually from the start. It offers guidance on how safety information is generated, flows, and can be used throughout the project's lifecycle. While all Health and safety risk information can be incorporated within an information model, PAS requires the contextualisation and categorising of hazards and risks to highlight the elevated risks that are critical. It also establishes a risk information cycle framework for the application of safety information through BIM processes and applications. The requirements of PAS can be applied equally to non-BIM projects. PAS identifies how to use Health and safety data to:

- Offer a safer and healthier environment for end-users
- Mitigate hazards and risks across the project's lifecycle
- Improve construction Health and safety performance
- Provide relevant health and safety information to the right people at the right time
- Reduce construction and operational costs

Finally, Directive 92/57/EEC on implementing minimum safety and health requirements at temporary or mobile construction sites will be associated with the framework. The proposed approach for BIM for Safety verification system aims to improve these three aspects by the following:

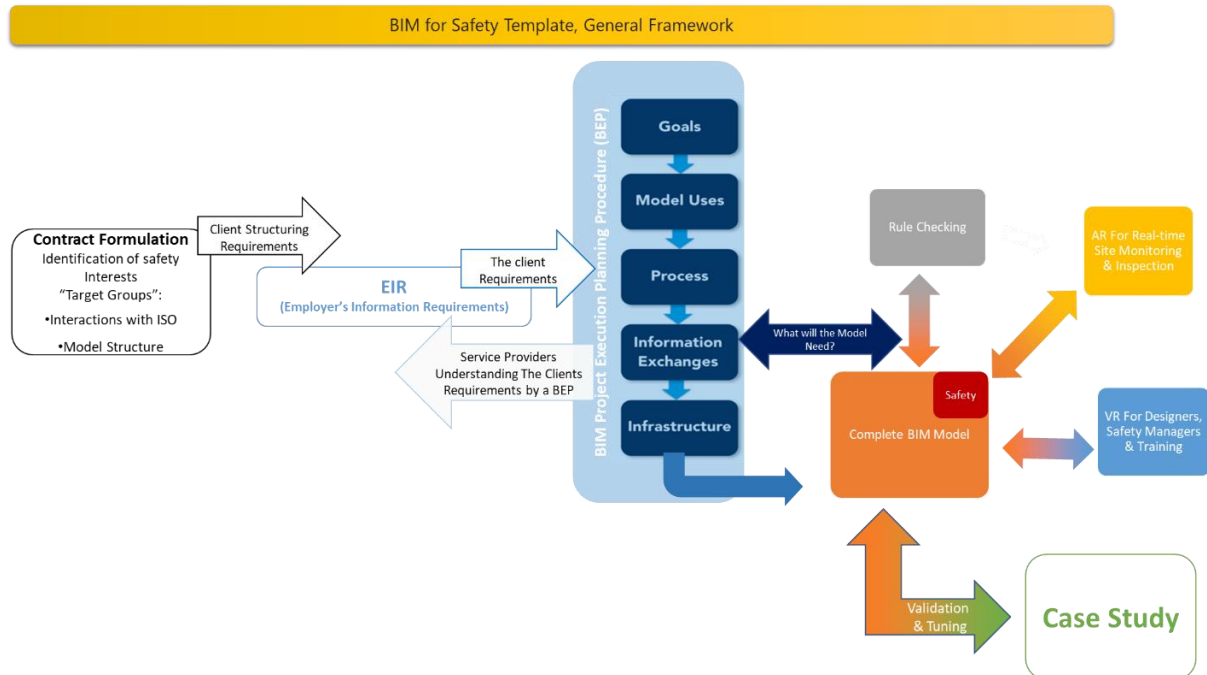


Figure 3 BIM for Safety Framework

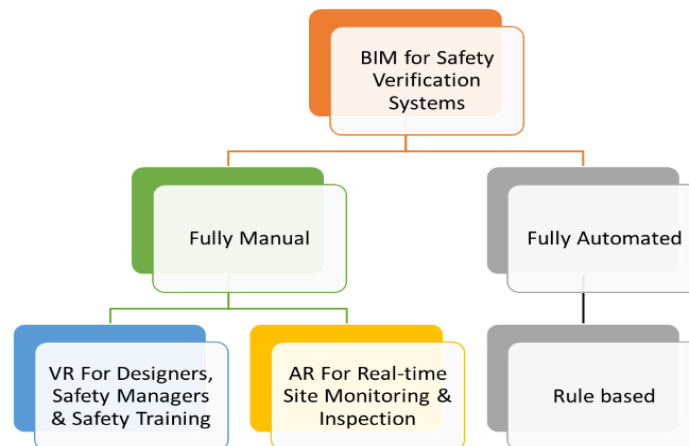


Figure 4 BIM for Safety Verification System

Detecting hazardous areas at a specific time

Since the system is made of a well-identified and structured BIM model, the model then could be introduced to automated rule checking for fully automated risk checking. One of the main problems of construction health and safety is that it is impossible to eliminate all risks due to the dynamic and complex aspect of the construction site. Consequently, several risks scenarios will be identified and analysed at an earlier stage, categorising them based on their Probability, severity, and exposure. Moreover, the rules for each risk will be illustrated. Hence, developing the BIM model with adequate requirements and Level of Development (LOD) facilitates automated rule checking [Figure 5](#).

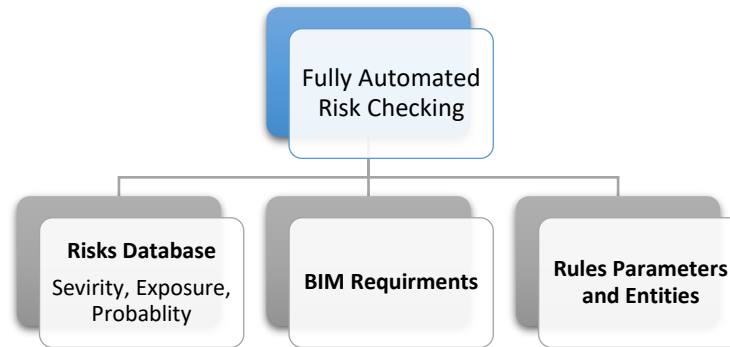


Figure 5 Fully Automated Rule Checking Components

Automated Rule checking aims to cover most of the risks; however, a manual approach will be taken for the risks that cannot be checked automatically. The manual approach is divided into off-site risk checking by using VR and on-site by using AR.

Monitoring and Inspection, and Training

VR will help in identifying risks starting from the design phase up until operation and management. VR can also assist in Health and Safety training. In comparison, AR will be mainly used for on-site inspection, monitoring, and training. To achieve this framework, the BIM model should be prepared with the essential requirements. The data will be transferred to an intermediate converter (e.g., Tridify) to transfer the BIM elements to a readable game engine (e.g., Unity) formats. Finally, the BIM data could be transferred and viewed in a Virtual Environment [Figure 6](#).

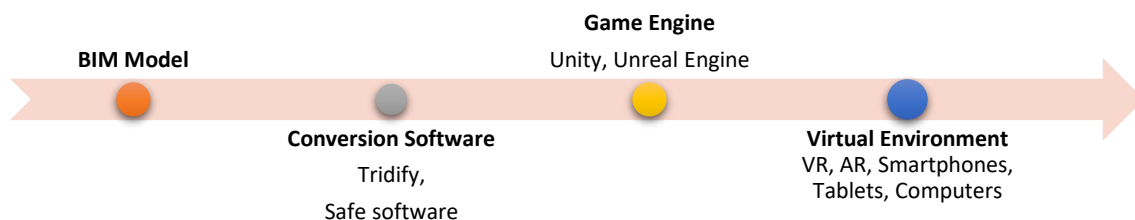


Figure 6 General BIM to Virtual Environment Importation process.

Limitations and Weaknesses

The framework is composed of several digital systems. Each of these systems represents some limitation. The framework's significant limitations are the workers' lack of expertise using digital tools, lack of collaboration between appointed parties, low demand from the owners, incompatibility of data transfer between appointed parties.

The widespread myths about BIM usage and the stubborn mindset of professionals toward validating the facts are delaying the AECO sector from fully integrating the emerged BIM technology. Moreover, the AECO sector is satisfied and is not willing to change the current practices.

As for BIM-based AR, limitations were primarily found in the data transfer due to some construction site's low connectivity levels regarding internet and GPS connections. Nonetheless, there are still constraints regarding non-geometric information being implemented in the AR systems.

Concerning BIM-based VR, software compatibility, the need to create an algorithm to enable the scan of all building objects and parameters, the level of realism of the models, and the implementation of an IFC interface to build a universal data component adopt different BIM packages. The lack of exportation features for the collaboration results. Furthermore, the time spent preparing the BIM model is still a relevant limitation.



Conclusions

The integration of BIM with Automated Rule checking, AR, and VR can indicate the same components of the BIM model by specifying the Level of Information Need, referring to BS EN 19650-1 defines the quality, quantity and granularity of information. Information can be in the form of geometric information (or Level of graphical Detail) and alpha-numeric (or Level of Information).

The proposed framework will be able to target safety planning, Visualization, safety management, training, automated rule checking, monitoring and inspection. The research aims to provide a general framework of a BIM-based safety system to improve the safety status of the overall construction lifecycle.

A Case Study will be made implementing it into an actual industrial project in Portugal. The case study will be presented to provide evidence for the developed system's functionality in coordinating concurrent onsite processes and foreseeing conflicts as well validating the framework with the assistance of safety professionals. The next step will be to elaborate on the proposed safety monitoring and inspection implementation in real practice and presents an illustrative example to showcase the added opportunities. This case also explains how the site planning outputs are interpreted into actual site activities and tasks. Demonstrating how the proposed methodology can assist in the identification of critical timeframes, dangerous onsite zones, and efficient logistics strategies. Finally, implementing the framework's site management component and exemplify a real cases' implementation process.

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BUILDING A 'SENSE OF PLACE' TO SUPPORT MENTAL HEALTH IN CONSTRUCTION: A CONCEPTUAL MODEL

Michelle Turner, Helen Lingard, James Harley

RMIT University, Australia

Correspondence: michelle.turner@rmit.edu.au

Abstract

Sense of Place (SoP) centres on community, belonging, and identity and is associated with psychological wellbeing. The SoP concept is underscored by a positive psychology approach which focuses on conditions and processes in the workplace that contribute to flourishing or optimal functioning. It is proposed that in construction, creating SoP in the workplace will yield benefits for workers' psychological wellbeing. In the construction industry SoP is a relatively understudied area. The conditions and processes which contribute to SoP are not well understood, and this presents as a gap in the literature. The aim of the research was to respond to this gap by identifying a set of protective workplace factors which contribute to SoP in construction, are mutually exclusive, and are measurable. An integrative literature review was undertaken and six components associated with SoP were identified: community, respect, life balance, support, resilience, and engagement. Each of the six components is defined, their relation to mental health is identified, and a set of scales is outlined. A limitation of the study is the lack of empirical evidence for the SoP components and associated scales. It is recommended that future research empirically evaluate the six components of SoP in a construction workforce setting. We acknowledge that developing SoP in construction projects is likely to be challenging due to the temporary nature of work and a transient workforce. However, given the high levels of mental ill-health in the construction industry, it is imperative that strategies seeking to promote mental health are encouraged and supported.

Keywords: construction, mental health, positive psychology, sense of place, wellbeing.

INTRODUCTION

Sense of Place (SoP) is used to describe the perception of place in connection with the qualities and attributes that distinguish a place from others, give it a sense of authenticity, and induce feelings of attachment and belonging (Foote and Azaryahu, 2009). SoP has been explored across many disciplines to describe the various aspects of human relationship with the natural environment (Hausmann et al. 2015). In the environmental psychology and sociology disciplines, SoP is focused on community, belonging, and identity and is associated with: 'exploring the dimensions of the people-place relationship; reduction of, and recovery from stress; psychological integrity and preventing mental illnesses' (Hausmann et al. 2015, p.121). SoP in the workplace has received minimal attention in the extant literature, and research has often focused on the physical characteristics of the workplace associated with wellbeing. Furthermore, much of the research on SoP in the workplace has been informed by office-based and knowledge workers (Foley, 2007; Miller et al. 2001). For example, Miller et al. (2001) focused on the interior setting of a workplace and operationalised SoP of knowledge workers to include comfort, control, noise, privacy, and personalization.

Much of the extant literature on workplace SoP has limited relevance to the construction workplace. Construction project teams usually consist of a wide range of occupations dispersed across multiple locations (Langford et al. 1995), therefore defining 'place' in a physical sense is somewhat challenging. Furthermore, projects are temporary in nature, and team members are often engaged for specific



periods to undertake specific tasks in a 'place' which is constantly evolving throughout the construction process.

In relation to SoP in the workplace, Foley (2007) considers the definition of work and this has relevance to construction as a 'place' of work. Foley (2007, p.864) contends that the workplace should not be conceived 'as zones or territories but as modes of workplace interaction and proximity - entered into or withdrawn for discrete purposes, and which incorporate a range of tasks, activities and social encounters'. Foley's (2007) definition of the workplace challenges us to look beyond the physical place of work when considering SoP in construction and focus on the interactions and tasks of construction work. For workers in construction, further research is required to explore characteristics of the workplace that enables SoP which supports mental health and wellbeing.

MENTAL HEALTH IN CONSTRUCTION

Mental ill-health is reported to 'cluster within' particular industries and occupations, with workers in male-dominated industries being at increased risk (Roche et al. 2016, p. 280). Construction is a male-dominated industry and its workers are a high-risk group for mental ill-health (Roche et al. 2016). A recent report undertaken on behalf of the Chartered Institute of Building revealed that construction industry workers are worse off than workers in other industries in terms of experiencing poor work-life balance, high workload, excessive travel time, technology overload, and unrealistic deadlines (Cattell et al. 2017). In a systematic review of mental ill-health risk factors in the construction industry, Chan et al. (2020) identified key risk factors for mental ill health as a lack of job control, welfare concerns, workplace hazards, job demands, workplace injustice, family, and lack of support.

There is an increasing emphasis on the workplace as a point of intervention for targeting the prevention of mental illness and the promotion of wellbeing (Harvey et al. 2014). The workplace is considered as an effective site of intervention for mental health promotion programs, particularly among men who are reported to have lower levels of mental health literacy and be less likely than women to seek help for personal difficulties (Roche et al. 2016). Roche et al. (2016) argue that:

- large numbers of people can be accessed through workplace interventions
- workplaces already comprise of existing infrastructure and frameworks to support the implementation of mental health and wellbeing programs, and
- addressing mental health as part of workplace occupational health and safety management activities reduces stigma and encourages help-seeking behaviour in relation to mental health.

While changing attitudes and behaviour in relation to mental ill-health is important, long term prevention measures also need to target the construction industry's culture and entrenched practices that contribute to the emergence of mental ill-health. Dextras-Gauthier et al. (2012) argue that the behaviours, structures and processes that produce adverse conditions of work are shaped by the values, assumptions and beliefs inherent in an industry or organisational culture. They argue that '...when dealing with mental health issues, including burnout, depression, and psychological distress, managers need to tread further upstream to identify those elements of organizational culture that are ultimately causing ill health' (Dextras-Gauthier et al. 2012, p.97).

POSITIVE APPROACH TO MENTALLY HEALTHY WORKPLACES

Many occupational health initiatives focus on reducing sickness, presenteeism or sickness absence, which are all known to present a high cost to organisations. However, it is increasingly recognised that workers who are mentally and physically healthy are also more productive, shifting the emphasis from prevention of ill-health to the promotion of good health in the workplace (Christensen, 2017). Hakanen and Schaufeli (2012) argue that workers' general wellbeing should be understood as being more than the absence of depressive symptoms. Rather, a state of general wellbeing also constitutes the presence of a positive state of life satisfaction. There is an increasing call for research that



investigates whether factors, other than those that cause ill-health, predict positive health (Torp et al. 2013). Understanding the determinants of positive wellbeing will enable the design and implementation of interventions that will create a psychologically healthy workplace.

Understanding the 'conditions and processes that contribute to the flourishing or optimal functioning of people, groups, and institutions' is the overarching goal of the positive psychology movement (Gable and Haidt, 2005, p.104). Positive psychology is based on the premise that there is a need to focus scientific research and interest 'on understanding the entire breadth of human experience, from loss, suffering, illness, and distress through connection, fulfilment, health, and well-being' (Linley et al. 2006, p.6).

In relation to workplace interventions, the positive psychology movement has contributed to a relatively recent managerial focus on the creation of mentally healthy workplaces, defined as workplaces in which:

- 'risk factors are acknowledged and appropriate action [is] taken to minimise their potential negative impact,' and
- 'protective or resilience factors are fostered and maximized' (Harvey et al. 2014, p.12).

Thus, in a mentally healthy workplace steps are taken to eliminate risk factors for loss, suffering, illness, and distress, as well as to create a context within which workers are able to flourish.

Henry (2005) draws on a positive psychology perspective (Seligman and Csikszentmihalyi, 2000) to consider the characteristics of a 'healthy organisation'. Henry (2005) contends that interventions which contribute to a healthy organisation can occur at four levels: the individual, the group, the organisation, and the inter-organisational. At the individual level, interventions focus on improving the psychological health of workers and seek to build strengths, enhance positive individual resources such as emotional intelligence and resilience, and promote wellbeing (Di Fabio, 2017; Green et al., 2017). At the group level, interventions focus on team building (belonging and social support), group training (promotes identifying, accepting, and working with diversity), creative thinking (healthy groups are open to creative challenges from members), and workplace relational civility (relational decency, relational culture, and relational readiness for positive interactions with other workers), which can reduce conflict in organisations (Di Fabio, 2017). At the organisation level, the focus is on making the organisation a more efficient and happy place to work in, creating an open culture characterised by sustained creativity and innovation, and promoting an organisational climate that supports positive relationships and leadership styles for the empowerment of workers through autonomy and self-organisation (Di Fabio, 2017). At the inter-organisational level, the focus is on making the boundaries of organisations more fluid and improving the relations between organisations. Partnerships, networking, and community involvement are emphasised at the inter-organisational level (Di Fabio, 2017).

RESEARCH CONTEXT

The research team was engaged by an Australian organisation to undertake an evaluation of its new SoP program. The organisation was leading a large and complex multi-site infrastructure project, and the SoP program was intended to support the mental health of its construction workforce. In developing the SoP program, the organisation identified four initial components: connection, belonging, respect and support. The research team was engaged to:

- 1) Undertake a review of the literature to identify the workplace conditions that contribute to SoP and enable high levels of mental health and wellbeing.
- 2) Identify a set of scales (in the form of a survey) that can be used to evaluate the SoP program.



In this research, SoP is defined in the context of interactions taking place at work for discrete purposes (Foley, 2007) that focus on community, belonging, and identity (Hausmann et al., 2015). The SoP definition is underscored by a positive psychology approach which focuses on conditions and processes that contribute to the flourishing or optimal functioning of workers (Gable and Haidt, 2005). In the construction industry, SoP is a relatively understudied area. The conditions and processes which contribute to SoP are not well understood, and this presents as a gap in the literature. The aim of the research is to respond to this gap by identifying a set of protective workplace factors which contribute to SoP in construction, are mutually exclusive, and are measurable.

METHOD

An integrative literature review method was used in the research. For newly emerging topics, Torraco (2005) contends that the purpose of the integrative literature review is to create initial or preliminary conceptualisations and theoretical models, rather than review old models. Furthermore, the purpose is usually not to cover all articles ever published on the topic but to combine perspectives and insights from different fields or research traditions (Snyder, 2019). In this study, perspectives were drawn from SoP, positive psychology, and organisational fields. The four phases of conducting a literature review according to Snyder (2019) guided the research: 1) design the review, 2) conduct the review, (3) analysis, and (4) write up the review. More specifically, the integrative literature review was undertaken to: 1) review the initial four components proposed by the organisation (connection, belonging, respect and support); 2) expand the review to identify and define protective factors supporting SoP and mental health; 3) ensure factors are mutually exclusive; 4) identify a scale for each of the protective factors. The following databases were searched: Emerald, Proquest, Business Source Premier (EBSCOhost), Expanded Academic (Gale), ISI Web of Science, and Science Direct (Elsevier). In addition to the databases, a book search of the library catalogue was undertaken, as well as a search of the grey literature. The following key terms were searched: sense of place, connection, belonging, respect, support, positive psychology, positive psychology workplace interventions, flourishing, mental health in construction. Inclusion criteria specified that the documents reviewed were evidence-based, from a reputable high-quality outlet, and in English.

Once components were identified, a review of associated scales was undertaken. The scales were selected according to the following criteria: satisfactory psychometric properties, alignment with component definitions, publicly available for use and free of charge. As the organisation stipulated that the evaluation tool (survey) should take no longer than ten minutes for workers to complete, the length and number of items was also considered important in scale selection. A critical analysis of relevant scales was undertaken, however sits outside the scope of this paper.

FINDINGS

Along with the initial four components (connection, belonging, respect and support) proposed by the organisation, the integrative literature review identified an additional four components: community, life balance, resilience and engagement which contribute to SoP and mental health, and take a positive psychology (protective) approach. As the full integrative literature review extends well beyond the specified length of this paper, we present a truncated version of the findings. From the literature review, six components (summarised in Table 1) were identified that were strongly, empirically linked to positive mental health outcomes, mutually exclusive, and contribute to SoP. Connection and Belonging were omitted as there was definitional overlaps with other components. Table 1 also outlines scales aligned with each of the components. Further information on the findings from the integrative literature review is available from Lingard et al. (2020).

Table 1: Sense of Place components



SOP component	Scale name	No. of items and factors	Citation
Respect	Civility Norms Questionnaire-Brief	4(1)	Walsh et al. (2012)
Support (supervisor)	Social Support from Supervisor Index	4(1)	Caplan. (1975)
Support (coworkers)	Social Support from Coworkers Index	4(1)	Caplan. (1975)
Community	Brief Sense of Community Scale	8(4)	Peterson et al. (2008)
Life balance	Work life balance	3(1)	Haar. (2013)
Resilience	Employee Resilience Scale	9(1)	Näswall et al. (2015)
Engagement	Oldenburg Burnout Inventory	16(2)	Demerouti et al. (2010)

1. Connection

The literature review identified that Connection has a strong definitional overlap with Support. There is also definitional overlap with Community and Belonging. Given the importance of definitional clarity, measurement of mutually exclusive concepts, and brevity of scales, the Connection component of SoP is addressed through a measure of Community and a measure of Support.

2. Belonging

The literature review identified that Belonging has a definitional overlap with Connection and Community. As previously stated, definitional clarity and measurement of mutually exclusive concepts are critical, therefore the Belonging component of SoP is addressed through a measure of Community.

3. Respect

Respect has been defined and operationalised in various ways within the organisational literature. For example, Bies and Moag (1986) define respect as being treated politely, while disrespect includes inconsiderate actions, use of abusive language, and coercion (Grover, 2013). De Cremer and Tyler (2005) refer to respect as how worthy and recognised one feels, while van Quaquebeke and Eckloff (2010) define respectful leadership as 'maintaining an appreciative attitude toward the other person and acting on the basis of this attitude even if one does not personally like or agree with the object of respect' (p. 344). Andersson and Pearson (1999) consider respect from a workplace incivility lens, defining incivility as 'low intensity deviant behaviour with an ambiguous intent to harm the target, in violation of workplace norms for mutual respect' (p.457).

A respectful workplace is one in which people feel worthy and recognised and incivility is not tolerated. In contrast, workplace civility reflects 'behavior that helps to preserve the norms for mutual respect at work; it comprises behaviors that are fundamental to positively connecting with another, building relationships, and empathizing' (Pearson et al. 2000, p.125). In the workplace, civility 'demands that one speaks in ways that are respectful, responsible, restrained, and principled and avoid that which is offensive, rude, demeaning, and threatening' (Gill and Sypher, 2009, p.55). Workplace incivility is associated with psychological distress and strategies to improve respect and civility in the workplace can significantly reduce burnout (Leiter et al. 2011).

In the workplace respect has been studied in the context of the organisational justice literature. Organisational justice refers to 'employees' perception of fairness in the organizational work systems and workplace relationships' (Pattnaik and Tripathy, 2019, p.58). Organisational justice has also been described as a personal evaluation about the ethical and moral standing of managerial conduct (Cropanzano et al. 2007). Cropanzano et al. (2007) contend that while justice contributes to workers'



relationships with their employer, injustice is reported to dissolve bonds within the work community. There is evidence that low organisational justice is a risk to the health of employees (Elovainio et al. 2002).

4. Social support

Social support refers to situations in which one person or group needs help to achieve an objective and another person or group offers resources to provide help (Dovidio et al. 2006). According to Brough and Pears (2004, p.472) workplace social support focuses on 'collaborative problem solving and sharing information, reappraising situations and obtaining advice from a variety of personnel such as colleagues, supervisors and managers (i.e. sources of social support)'. In the workplace, social support is defined as the degree to which individuals perceive that their wellbeing is valued by workplace sources, such as supervisors and the broader organisation in which they are embedded, and the perception that these sources provide help to support this wellbeing (Eisenberger et al. 2002; Kossek et al. 2011). Kossek et al (2011, p.291) conceptualise workplace social support as '(a) emanating from multiple sources, such as supervisors, coworkers, and employing organisations; and (b) distinguished by different types or foci of support that are either 'content general' or 'content specific.' General work support refers to the degree to which workers perceive that supervisors or employers care about their global wellbeing on the job through providing positive social interaction or resources. Content-specific support refers to perceptions of care and the provision of resources to reinforce a particular type of role demand.

There is strong evidence of the association between social support and health, including mental health (Kawachi and Berkman, 2001). Perceived organisational support is positively linked to worker engagement and wellbeing (Caesens et al. 2016) and negatively related to burnout (Walters and Raybould, 2007). The absence of support in a supervisor-employee relationship has also been observed to have an impact on the performance of employees, their satisfaction at work and on the engagement and burnout of the affected employees (Baruch-Feldman et al, 2002; Neves and Eisenberger, 2014). Johnson and Hall (1988) incorporated social support into the Job Demand-Control model of occupational stress (Karasek, 1979) and demonstrated that in environments characterised by high demands and low control, workers experienced reduced levels of strain when social support was high.

5. Community

Sense of community (SOC), also referred to as psychological sense of community, refers to the fundamental human phenomenon of collective experience (Peterson et al. 2008). McMillan and Chavis (1976, p.9) describe SOC as 'a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together'. A workplace community is identifiable as a set of formal and informal networks of individuals who share a common association (Burroughs and Eby, 1998). In a work setting, Lambert and Hopkins (1995, p.152) define a sense of community as 'mutual commitment between workers and their employing organization'. Lambert and Hopkins (1995) draw on Mowday et al. (1982, p.153) to clarify that mutual commitment can be understood within the context of organisational commitment, described as 'the relative strength of an individual's identification with and involvement in a particular organization, which is characterized by belief and acceptance of organizational goals, and values, willingness to exert effort on behalf of the organization, and a desire to maintain a membership in that organization'.

SOC is commonly described as a multidimensional construct in which reference is often made to McMillan and Chavis' (1986, p.9) four components of: membership; influence; integration and fulfillment of needs; and shared emotional connection. A sense of community is positively related to experiencing higher levels of mental wellbeing (Boyd and Nowell, 2017; Peterson et al. 2008).



6. Life balance

Life balance describes a situation in which workers experience 'satisfaction and perceptions of success in meeting work and nonwork role demands, low levels of conflict among roles, and opportunity for inter-role enrichment, meaning that experiences in one role can improve performance and satisfaction in other roles as well' (Kossek et al. 2014, p,X). Life balance is strongly and consistently positively related to job and life satisfaction and negatively related to anxiety and depression across samples from seven different countries/cultures (Haar et al. 2014).

Positive interaction between work and family has been linked to psychological wellbeing. For example, Allis and O'Driscoll (2008) report that nonwork-to-work facilitation is associated with higher levels of employee wellbeing, while Haar and Bardoel (2008) report that positive spill-over between work and family life was negatively associated with psychological distress and turnover intention in a sample of Australian workers. Van Steenberge et al. (2007) also found work-to-family facilitation contributed to the prediction of previously reported work-family outcomes, including work satisfaction, organisational commitment, job performance, home performance, home commitment, home satisfaction and general life satisfaction, over and above variance explained by traditional measures of work-family conflict. In a two-staged longitudinal study, Innstrand et al. (2008) similarly found that work-to-family facilitation at 'time one' was associated with lower levels of employee burnout at 'time two'.

7. Resilience

Resilience is increasingly understood, not as a stable set of personal characteristics, but as a process arising from the interplay of the individual with their work environment (World Health Organization, 2017). In the workplace, resilience describes the ability of an individual worker or work group to respond to everyday problems and challenges associated with work and be able to 'bounce back' when setbacks are encountered and remain effective in challenging situations. Beyond this, resilience in the workplace also incorporates the lasting benefit and learning that occurs through successfully coping with adverse situations (Cooper et al. 2013). Resilience in the workplace is positively linked to mental health (Kinman and Grant, 2011). Importantly workers' resilience can be facilitated by the work environment, including leadership and the prevailing workplace culture (Näswall et al. 2015).

Central to models of resilience are the inclusion of protective factors which are critical for managing stressful events effectively to either mitigate or eliminate risk. According to Windle (2011), protective factors are the defining attributes of resilience. Some studies distinguish the individual level protective factors as assets, while resources are regarded as external to the individual (Fergus and Zimmerman, 2005; Sacker and Schoon, 2007):

- internal protective factors are individual qualities or characteristics/capabilities that are responsible for fostering resilience and are specific to the individual, and
- external protective factors are positive environmental support structures from the environment in which the individual is situated.

8. Engagement

Work engagement has been described as 'a positive, fulfilling, affective-motivational state of work-related well-being' (Bakker et al. 2008, p187-188). Work engagement is often regarded as the opposite of job burnout. For example, Maslach and Leiter (1997) suggested engagement comprises energy, involvement and effectiveness, which are the direct opposites of the three burnout dimensions of exhaustion, cynicism and diminished personal efficacy. Other researchers have defined and operationalised work engagement as a distinct construct to burnout. For example, Schaufeli et al. (2002) define work engagement as 'a positive, fulfilling, work-related state of mind that is



characterized by vigour, dedication and absorption' (p.74). The components of work engagement have been further defined as follows:

- vigour is characterised by 'high levels of mental resilience while working, the willingness to invest effort in one's work and persistence even in the face of difficulties'
- dedication describes 'being strongly involved in one's work and experiencing a sense of significance, enthusiasm, inspiration, pride and challenge,' and
- absorption is characterised by 'being fully concentrated and happily engrossed in one's work, whereby time passes quickly, and one has difficulties with detaching oneself from work.' (Bakker et al. 2008, p.188)

Innstrand et al. (2012) directly tested for a relationship between work engagement and symptoms of anxiety or depression using a two-wave longitudinal dataset (with a two-year time interval). They report the statistical model that positioned work engagement as a predictor of symptoms of anxiety or depression was stronger than an alternative model in which work engagement was positioned as the outcome of experiencing symptoms of anxiety or depression. Thus, the direction of causality is likely to be from engagement to the absence of mental ill-health. In particular, the lagged negative effect of vigour on symptoms of depression and anxiety over the two-year data collection period provides evidence that work engagement has a positive protective effect on mental health. Innstrand et al. (2012) argue that this suggests that, in addition to eliminating organisational risk factors for mental ill-health, workplaces should also focus on creating the conditions in which workers can flourish. Hakanen and Schaufeli (2012) similarly report that a positive state of work engagement negatively predicted depressive symptoms over a seven-year longitudinal study.

CONCLUSION

Much of the research on SoP in a work setting has focused on the physical characteristics and conditions of the workplace, which does not readily translate to a construction project environment. Importantly, we position the 'place' of work in construction as being the point at which work interactions take place rather than being represented physically. This is a critical point as the physical 'place' of a construction project is constantly evolving throughout the construction process. Furthermore, work on one construction project can occur simultaneously across multiple, geographically dispersed work sites. For example, work tasks contributing to one project may take place virtually (such as working from home), from a corporate office, onsite in the site office, and onsite in direct construction activity. Our research contributes to the literature on SoP by identifying the workplace conditions that can contribute to SoP and enable high levels of mental health and wellbeing for construction workers. From the literature, six components were identified that were strongly, empirically linked to positive mental health outcomes. Accompanying each component is a scale. It is proposed that the set of scales can be used as a tool for assessing SoP in construction project environments. A limitation of the study is the lack of empirical evidence for the SoP components and the associated scales. It is recommended that future research empirically evaluate the six components of the SoP in a construction workforce setting. This can be done by administering the SoP measure with construction workers and exploring the relationships between the six components and to the broader SoP concept.

Mentally healthy workplaces are described as those which foster and maximise protective factors. The new SoP conceptual model is positioned within a positive psychology paradigm and offers a process by which organisations can create a context for workers to flourish. Mentally healthy workplaces are also described as those which seek to acknowledge risk factors and take appropriate action to minimise their potential negative impact. Construction is known as a high-demands industry in which work-based hazards can create adverse and hostile environments that are harmful to workers' mental health. In order to have a positive impact on mental health, implementation of a SoP program in



construction must be accompanied with the removal of harmful work conditions which lead to mental ill-health.

We acknowledge that the development of SoP in construction projects is likely to be challenging because construction projects are temporary coalitions of permanent and temporary organisations working interdependently to achieve project outcomes, while also managing their own business interests (Berggren et al. 2001). There is a heavy reliance on subcontracting to undertake manual/non managerial construction work and the workforce is heavily transient. However, given the high levels of mental ill-health in the construction industry, it is imperative that strategies seeking to promote mental health are encouraged and supported. It is anticipated that initiatives designed specifically to create a sense of place in the construction project environment will yield benefits for workers' psychological wellbeing.

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Developing an Assessment Tool for Evaluating the Mental Health Levels of Construction Project Organizations in Australia

Xiaohua Jin, Robert Osei-Kyei, Srinath Perera, Bashir Tijani

Western Sydney University, Australia

Correspondence: 17872544@student.westernsydney.edu.au

Abstract

Construction project organization is a stressful working environment that exposes project management practitioners (PMPs) to poor mental health, which is a significant social and economic problem in Australia. The New South Wales (NSW) government, Australia government launched training on how businesses can attain mentally healthy workplaces through indicators for mental healthiness evaluation of project organization, where construction projects are executed. While acknowledging the significance of NSW initiative in promoting mentally healthy construction p environments, indicator assessment tool to assist construction businesses in NSW in evaluating mental healthiness of construction project environments is lacking. The paucity of an assessment tool for mentally healthy construction project environment prevented detection of unprecedented risk inimical to the mental health of project management practitioners in NSW, Australia. In this regard, this paper aims to develop an indicator assessment tool in the form of a data spreadsheet, using mental health indicators. Mental health assessment tool would assist project managers and stakeholders to accurately and reliably evaluate the mental healthiness of their construction project organisations in NSW, Australia. More importantly, with the mental health assessment tool, project managers can compare the mental health status of different project organisations on the same basis. The paper adopted systematic literature review to identify indicators for mentally healthy environments from various sectors to build a user-friendly indicators assessment tool for evaluating mental health level of construction project organizations.

Keywords: Construction project organization; Indicators; Mental health ; Assesment tool

Introduction

Complexity of construction project organizations that involves management of multiple project stakeholders, construction programs planning, human resources management and budget control makes PMPs susceptible to poor mental health. Globally, there is pervasiveness of mental health problems as various reports confirmed the alarming statistics of PMPs suffering from mental health. In the UK, 70% of construction project management professionals suffered from stress, anxiety or depression. Likewise, in Australia, 25.1% of construction workers were diagnosed with mental illness. Developing economies were not immune from the problem as report indicates that 68% of PMPs experienced occupational stress in the Malaysian construction industry. These alarming statistics signified the intensity of the significant problem plaguing the industry.

Burgeoning interest in the mental health of PMPs sparked proliferation of mental health literature to promote positive mental health in construction project organizations through various strategies. For instance, Haynes and Love (2004) revealed coping mechanisms as individual practices for addressing mental health problems in construction sectors. Similarly, Leung et al. (2006) established the potential of coping mechanisms in managing stress leading to poor mental health among PMPs. Recently, scholars called for organizational interventions for mental health to address the limitations in coping behaviours in tackling psychosocial risks inherent in construction projects causing poor mental health. Organizational supports were established as organizational interventions providing social supports to



reduce psychosocial risks and promote mental health (Love et al. 2010). Yang et al. (2017) introduced company management system comprised of staff management institution, project management institution and organization project management institution to mitigate job stress and job burnout.

Undoubtedly, extant studies contributed significantly to mental health management by revealing individual and organizational strategies for improving mental health; however, causes of poor mental health ascribed to design of construction project organizations opened a new scholarship on assessment tool for evaluating mental health level status of construction project organizations to prevent psychosocial risks exposing PMPs to poor mental health. Construction project organization designs involve the combination of project and organizational management characteristics, including, human resources management (Guest 2017), organizational culture (Dextras-Gauthier and Marchand 2018), and leadership shaping mental health (Arnold 2017). Hence, optimum solution to pervasiveness of mental health in construction sectors is to develop an assessment tool to evaluate construction project organizations mental health status to function as proactive measures for psychosocial risks. Based on this, the NSW government, Australia, initiated the development of mental health assessment tool for construction businesses to evaluate the mental health level of their organizations. In spite, the excessive demand by NSW government, Australia, sparse attention was paid to research on the development of assessment tool for evaluating mental health status of construction project organization to reduce psychosocial risks and promote mental health. Against this backdrop, this study aims to developed an assessment tool for evaluating mental health level of construction project organizations in NSW, Australia.

Mentally healthy organization

The concept of mentally healthy organization is not new, as numerous industries including manufacturing and hospitality utilized the concept to comprehend the critical role of organizational design on the mental health of workforce. However, knowledge of mentally healthy organization is limited in construction project organizations due to scanty studies on relationship between construction project organization design and mental health. According to Queensland (2014), mentally healthy organization is an organization promoting workplace practices that support positive mental health. It refers to an organization that eliminates and minimises mental health and safety risks by identifying and assessing psychosocial hazards. Mentally healthy organization is characterized by intentional, systematic and collaboration efforts to maximize employee mental health and productivity by providing well-designed and meaningful jobs (NSW Government 2017).

Mentally healthy construction project organization reflects the extent to which the project organization promotes mental health. A mentally healthy construction project organization may exhibit a high or low level of mental health status depending on the organization and project characteristics representing the indicators for assessing mentally healthy workplace. For this study, mentally healthy construction project organizations mainly consider the mental health of PMPs and not other construction workers.

Development of assessment tool for mentally healthy construction project organizations

Operational process of the assessment tool for mentally healthy construction project organizations mandated the utilization of indicators to be input into the assessment tool to estimate the mental health status of the project organizations. Therefore, in this study, developmental process of the assessment tool commenced with an extensive literature review to identify indicators for mentally healthy workplace. The indicators were used to develop questionnaire survey administered to four experts- Three industrial experts (project managers and a quantity surveyor) and academics researching mental health in the construction industry. Expert opinion was selected due to judgmental information required to rank the identified indicators and inaccessibility to construction sites due to COVID-19 lockdown in NSW. The questionnaire was designed on five points Likert scale : (1= Less

important and 5 = Extremely important) to obtain the ranking for calculating the mean values of the indicators. Fuzzy synthetic evaluation was adopted to develop an index for obtaining the weighted attribute for each category of indicators.

Convenience sampling underpinned the selection of industry experts drawn from the Australian Institute of Project Management (AIPM) based on their academic qualifications and project management experience. Knowledge resources nomination worksheet comprising of five experts was developed to highlight their educational qualifications, project management experiences and occupational health and safety experiences. Based on the nomination worksheet, two experts were ranked as highly knowledgeable to provide expert opinions on the subject matter. The two industrial experts possessed Master degree in project management with 12 years experience and other attained Bachelor degree in quantity surveying with 5 years experience. As for the academic expert, the experts were recruited through a literature search to identify academic experts that contributed to mental health in the construction. Due to the time frame, seven academic experts were contacted but only one accepted to participate in the study. The academic expert who participated in the study possessed a Doctoral degree with 3 publications on mental health.

Indicators for mentally healthy organization

Indicator refers to the parameter, which provides information about the condition of the phenomenon, environment or area with a significance extending beyond that directly associated with parameter value (OECD 1993). Walz (2000) defined indicator as a variable that explains the state of a system. In the context of mentally healthy project organization, indicators represent variables measuring the mental health condition of a project organization for decision making. Aggregation of the measurements obtained from the indicators determine the mental health status of the project organization. **Table 1** shows the lists of indicators obtained from a systematic review of mental health literature

Table 1. List of mental health management indicators

	Indicators	References
Strategy indicators	1.Provision of clearer project goals	(Arnetz and Blomkvist 2007); (Baptiste 2009)
	2. Business strategy emphasis non-selection of unhealthy project.	(Superfriend 2020)
	3. Policy mandating leaders to participate in mental health and well-being training.	(Baptiste 2009); (Superfriend 2020)
	4. Provision of good mental health policy, strategy or action plan.	(Superfriend 2020)
	5. Provision of clear structures to ensure transparent project decision making.	(Arnetz and Blomkvist 2007); (Superfriend 2020)
	6. Provision of policies to ensure that any changes in the workplace are managed in a polite way.	(Superfriend 2020)
	7. Provision of policies eradicating bullying, harassment and physical violence.	(Nwaogu and Chan 2020)
	8. Provision of clear expectation that all leaders should role model that values of the workplace.	(Superfriend 2020)
Structure indicators	9. Organization build strong relationship with project stakeholders.	(Agervold 1991); (Bergh et al. 2014)
	10. Organization avoid contradictory project demand.	(Arnetz and Blomkvist 2007)



	11. Organization provides clear project duties and responsibilities.	(Kroth et al. 2007)
	12. Organization provides opportunities to meet superiors on any project work related matters.	(Superfriend 2020)
	13. Organization established strong teamwork among construction workforce.	(Agervold 1991); (Baptiste 2009)
	14. There is a safe physical working environment.	(Kroth et al. 2007)
	15. Organization provides support to control project work.	(Parsons et al. 2006)
	16. Realistic project deadline.	(Ajayi et al. 2019)
	17. Flexibility in work schedules.	(Arwedson et al. 2007)
	18. Workplace free from excessive noise and temperature.	(Superfriend 2020)
	19. Leaders are accessible when needed and listen to workers.	(Superfriend 2020)
	20. Leaders create a sense of cohesion within work teams.	(Superfriend 2020)
	21. Proper conflict management system.	(Superfriend 2020)
Process indicators	22. Access to project information for performing construction works.	(Gustavsson 2016)
	23. Construction workers participate in project decision making.	(Gustavsson 2016)
	24. There is proper project communication.	(Arwedson et al. 2007)
	25. Organization provides useful and constructive feedback.	(Superfriend 2020)
	26. Construction workers are generally highly engaged with their work.	(Agervold 1991)
	27. Appropriate staffing of construction workforce in a project.	(Kroth et al. 2007)
Reward indicators	28. Reward and recognition are received for good work.	(Baptiste 2009)
	29. Organization provides support to help people practice good work/family/life integration.	(Arwedson et al. 2007); (Baptiste 2009)
	30. Provision of stress assistance programs.	(Nwaogu and Chan 2020)
	31. Provision for assistance for non-work stressors such as marital and family issue.	(Nwaogu and Chan 2020)
	32. Provision of mental health literacy programs.	(Superfriend 2020)
	33. Organization provides financial Aids for construction workers.	(Nwaogu and Chan 2020)
Peoples indicators	34. Social interactions among construction workers in a project.	(Bergh et al. 2014)
	35. Leaders actively provide opportunities to develop professionally.	(Superfriend 2020)
	36. Adequate project management training.	(Assesment 1982)
	37. Open discussion about issues that affect mental health and well-being.	(Superfriend 2020)
	38. There is a strong support from colleagues.	(Bergh et al. 2014)

Fuzzy synthetic evaluation

Fuzzy synthetic evaluation (FSE) is an evaluation modelling technique used in occupational and safety research and engineering management to quantify multi-evaluations, multi-levels, and multi-attributes (Hu et al. 2016; Osei-Kyei and Chan 2017). The technique is an application of the fuzzy set

theory (Ameyaw and Chan 2015). In this study, it is regarded as an appropriate tool for developing mental health management index (MHMI) equation for construction projects.

(1) Establish a basic set of mental health management indicators $M = [m_1, m_2, m_3, \dots, m_n]$; where m = identified mental health management indicators; n = number of mentally healthy indicators.

(2) Establish set of grading alternatives as $L = [L_1, L_2, L_3, \dots, L_n]$ where L = rating measuring scale; and n = number of classifications in the measuring scale. This study adopted 5-point Likert scale (L_1, L_2, L_3, L_4, L_5), for instance where L_1 = least important, L_2 = fairly important, L_3 = important, L_4 = very important, L_5 = extremely important.

(3) Set the weightings (W) for each mental health management indicator using the following equation:

$$Wi = \frac{Mi}{\sum_{i=1}^5 Mi} \quad 0 \leq Mi \leq 1, \quad \sum Wi = 1;$$

where Wi = weighting; Mi = mean score of the management indicator; and $\sum Wi = 1$ is the mean rating sum.

(4) Apply a fuzzy evaluation matrix (Ri) for each management indicator

$$Ri = (rij)m \times n$$

Where rij = degree to which alternative L_j satisfies the criterion f_j ; and m = mean score.

(5) Assess membership function for overall mentally health management indicators by calculating the weighting vector and fuzzy evaluation matrix using the following equation.

$$D = Wi \circ Ri$$

Where D = final FSE evaluation matrix; and O = fuzzy composition operator.

(6) Normalisation of FSE evaluation matrix to develop mental health management indicator index (MHI) using the following equation

$$MHMI = \sum_{i=1}^5 D \times L$$

Where D = final evaluation matrix; and L = the scale measurement for the set of grade categories.

Table 2. Mean rating and weights of mental health management indicators

Code	Factors	Mean for IND	Weightings for each IND	Total Mean for each category	Weightings for each category
IND1	Provision clearer project goals to construction workers	3.01	0.12		
IND2	Business strategy emphasis non-selection of unhealthy project	2.80	0.12		
IND3	Policy mandating leaders to participate in mental health and well-being training	2.40	0.10		
IND4	Provision of good mental health policy, strategy or action plan.	3.60	0.15		
IND5	Provision of clear structures to ensure transparent project decision making	3.01	0.12		



IND6	Provision of policies to ensure that any changes in the workplace are managed in a positive way	3.05	0.13		
IND7	Provision of policies eradicating bullying, harassment and physical violence	3.44	0.14		
IND8	Provision of clear expectation that all leaders should role model the values of the workplace	2.98	0.12		
Category 1	Strategy indicators			24.29	0.26
IND9	Organization build strong relationship with project stakeholders	3.46	0.08		
IND10	Organization avoid contradictory project demand	3.17	0.07		
IND11	Organization provides clear project duties and responsibilities	3.02	0.07		
IND12	Organization provides opportunities to meet superiors on any project work related matters	3.61	0.08		
IND13	Organization established strong teamwork among construction workforce	3.45	0.08		
IND14	There is a safe physical working environment	3.32	0.08		
IND15	Organizational provides support to control project work	3.40	0.08		
IND16	Realistic project deadline	3.97	0.09		
IND17	Flexibility in work schedules	2.61	0.06		
IND18	Workplace free from excessive noise and temperature	3.79	0.09		
IND19	Leaders are accessible when needed and listen to workers.	3.01	0.07		
IND20	Leaders create a sense of cohesion within work teams.	3.30	0.08		
IND21	Proper conflict management system	2.70	0.06		
Category 2	Structure indicators			42.81	0.46
IND22	Access to project information for performing construction works.	3.49	0.21		
IND23	Construction workers participate in project decision making	3.15	0.19		
IND24	There is proper project communication	3.19	0.19		
IND25	Organization provides useful and constructive feedback	2.84	0.17		
IND26	Construction workers are generally highly engaged with their work	2.50	0.15		
IND27	Appropriate staffing of construction workforce in a project	3.06	0.18		
Category 3	Process indicators			18.23	0.20



IND28	Reward and recognition are received for good work	2.88	0.17		
IND29	Organization provides support to help people practice good work/family/life integration	3.16	0.19		
IND30	Provision of stress assistance programs	2.53	0.15		
IND31	Provision for assistance for non-work stressors such as marital and family issue	2.90	0.17		
IND32	Provision of mental health literacy programs	2.81	0.17		
IND33	Organization provides financial Aids for construction workers	2.71	0.16		
Category 4	Rewards indicators			16.99	0.18
IND34	Social interactions among construction workers in a project	2.91	0.20		
IND35	Leaders actively provide opportunities to develop professionally	2.53	0.17		
IND36	Adequate project management training	3.30	0.22		
IND37	Organizational culture encourages open discussion about issues that affect mental health and wellbeing	2.87	0.19		
IND38	There is a strong support from colleagues	3.16	0.21		
Category 5	Peoples indicators			14.77	0.16
	Total Categories			92.80	

Mathematical index for mentally healthy evaluation based of FSE;

$$\text{MHMI} = (0.285 \times \text{Strategy Indicators}) + (0.225 \times \text{Structure Indicators}) + (0.125 \times \text{Process Indicators}) + (0.117 \times \text{Reward Indicators}) + (0.247 \times \text{People Indicators})$$

Assessment tools

Development of the mentally healthy assessment tool for construction project organization in NSW, Australia commenced by inputting the 38 indicators into a Microsoft Excel sheet to assist practitioners in rating the level of their implementation (Scale 1-5). Total rating earned for each category was evaluated by adding the rating ascribed to individual indicator in the category. Moreover, the attributed weighted score was calculated by dividing the total rating score acquired by maximum rating score multiply by the weighting attributed to each category in the mathematical index. For example, the weighting for strategy indicators is 0.285 and 0.225 is for structure indicators. The final result of the assessment is estimated by adding all the attributed weighted scores.

Please rate the below mental health indicators based on their level of implementation in your construction project organization using Likert scale

1= Not implemented; 2 = Partially implemented; 3 = Somewhat implemented; 4 = Moderately implemented; 5 = Fully implemented



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Strategy indicators		Rating Earned
IND1	Provision clearer project goals to construction workers	
IND2	Business strategy emphasis non-selection of unhealthy project	
IND3	Policy mandating leaders to participate in mental health and well-being training	
IND4	Provision of good mental health policy, strategy or action plan.	
IND5	Provision of clear structures to ensure transparent project decision making	
IND6	Provision of policies to ensure that any changes in the workplace are managed in a positive way	
IND7	Provision of policies eradicating bullying, harassment and physical violence	
IND8	Provision of clear expectation that all leaders should role model the values of the workplace	
Total Rating Earned		0
Attributed Weighted Score		0
Structure indicators		Rating Earned
IND9	Organization build strong relationship with project stakeholders	
IND10	Organization avoid contradictory project demand	
IND11	Organization provides clear project duties and responsibilities	
IND12	Organization provides opportunities to meet superiors on any project work related matters	
IND13	Organization established strong teamwork among construction workforce	
IND14	There is a safe physical working environment	
IND15	Organizational provides support to control project work	
IND16	Realistic project deadline	
IND17	Flexibility in work schedules	
IND18	Workplace free from excessive noise and temperature	
IND19	Leaders are accessible when needed and listen to workers.	
IND20	Leaders create a sense of cohesion within work teams	
IND21	Proper conflict management system	
Total Rating Earned		0
Attributed Weighted Score		0
Process Indicators		Rating Earned
IND22	Access to project information for performing construction works	
IND23	Construction workers participate in project decision making	
IND24	There is proper project communication	
IND25	Organization provides useful and constructive feedback	
IND26	Construction workers are generally highly engaged with their work	
IND27	Appropriate staffing of construction workforce in a project	
Total Rating Earned		0
Attributed Weighted Score		0
Reward Indicators		Rating Earned
IND28	Reward and recognition are received for good work	
IND29	Organization provides support to help people practice good work/family/life integration	
IND30	Provision of stress assistance programs	
IND31	Provision for assistance for non-work stressors such as marital and family issue	
IND32	Provision of mental health literacy programs	
IND33	Organization provides financial Aids for construction workers	
Total Rating Earned		0
Attributed Weighted Score		0
Peoples Indicators		Rating Earned
IND34	Social interactions among construction workers in a project	
IND35	Leaders actively provide opportunities to develop professionally	
IND36	Adequate project management training	
IND37	Open discussion about issues that affect mental health and wellbeing	
IND38	There is a strong support from colleagues	
Total Rating Earned		0
Attributed Weighted Score		0
Final result of the assesment		0



Discussion

The study's findings revealed that strategy, structure, process, reward and people indicators are contributors to mental level in construction project organizations. This is consistent with the findings of Ipsen and Jensen (2012), on the impact of organizational design components on work stress in knowledge work. Moreover, critical analysis of results shows that indicators that constitute each category have different weighting attributes underpinning the development of assessment tools. For strategy indicators, provision of good mental health policy was rated as the most important contributor while policy mandatory leaders to participate in mental health policy was rated as least important. This finding supports the argument of De Silva et al. (2017), on rating of stress management policy and leadership support for occupational stress management in large construction projects. Realistic project deadline is the most highly rated indicator, while flexibility in work schedule is the least rated indicator under structure indicators. This finding correlates with the study of Ajayi et al. (2019), on critical factors causing work stress among construction professionals.

Further, findings from the rating of process indicators indicate that access to project information is the most important contributor and workers engagement is the least important. This finding is consistent with the findings of Leung et al. (2008c), on stressors causing work stress. As for reward indicators, provision of support for work-family life is the most highly rated and provision of stress assistant is the least important. Project management training is highly rated indicator and provision of opportunity by the leader to develop professionally is considered the least rated. This finding is supported by De Silva et al. (2017) in primary and secondary intervention for occupational stress.

Limitations

Limitation of the study is the small number of experts used in ranking the indicators and invalidation of the assessment tool to establish the practicality in the construction industry. In future, this study will validate the tool through case studies after lifting the Covid-19 lockdown in NSW.

Conclusion

Relationship between organization design and mental health sparked demand for an assessment tool for mentally healthy construction project organizations to evaluate the mental health status of the project organization to prevent exposure of PMPs to poor mental health. To achieve this, extensive literature was conducted to identify the mental health management indicators. The extracted indicators were subjected to expert opinion to rank the level of importance of these indicators. Moreover, FSE was adopted to generate a mathematical index to facilitate the development of assessment tool for mental health. After the mathematical index, the indicators were transferred to Microsoft Excel sheet to estimated the total rating earned, attributed weighted score and final result of the assessment tool.

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JOB QUALITY AND CONSTRUCTION WORKERS' MENTAL HEALTH: A LIFE SPAN DEVELOPMENTAL PERSPECTIVE

Helen Lingard, Payam Pirzadeh, Rita Zhang, Michelle Turner

RMIT University, Australia

Correspondence: helen.lingard@rmit.edu.au

ABSTRACT

The research aimed to examine whether the factors that impact manual/nonmanagerial construction workers' mental health change with age. Specifically the research sought to identify, compare and contrast the characteristics of job quality that are related to mental health in three groups of construction workers in varying age brackets (young, middle-aged and older). Data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey was analysed to explore the relationship between job quality and health in Australian manual/non-managerial construction workers. Drawing on a life span developmental perspective, participants were divided into groups according to their age. Longitudinal statistical analysis was conducted to examine the association between four identifiable aspects of job quality and participants' self-reported mental health. The relationships varied by age groups, suggesting that psychosocial risk factors shape construction workers' health differently as they transition from an exploration phase (young workers), through an establishment phase (middle-aged workers) to a maintenance phase (older workers). The findings highlight the need to develop targeted approaches to protecting and promoting the mental health of construction workers in different age groups.

Keywords: mental health, wellbeing, construction

HEALTH AND WELLBEING EXPERIENCES OF CONSTRUCTION WORKERS

Ageing and health in the construction workforce

Project-based construction work is physically and psychologically demanding. Even compared to other blue-collar occupations, construction workers experience high levels of permanent work incapacity at a relatively young age (Arndt et al., 2005). Many construction workers are forced to stop working due to health problems before they reach the pension age (Brenner & Ahern, 2000; Welch, 2009; Oude Hengel et al. 2012). In Germany it is estimated that 63% of construction workers retire early due to permanent disability (Siebert et al., 2001).

The Australian construction industry's workforce is relatively young, with 42% of construction workers aged between 15 and 34 compared to 38% across all industries, and 35% of construction workers over 45 compared to 40% for all industries (ABS, 2021). However, consistent with broader demographic trends, the Australian construction workforce is ageing. The percentage of the construction industry's workforce aged 55 or over increased by 6.1% between 2000 and 2020, reaching 16.6% in November 2020. The changing workforce age profile highlights the need to consider potential impacts of ageing on the health and wellbeing of construction workers.

As people age, they naturally experience physical and cognitive changes, which can have implications for health and wellbeing at work. These changes include reductions in physical work ability, which has implications for industries that are characterised by physically demanding work, including construction (Kenny et al., 2008). Ringen et al. (2015) report elevated mortality among older construction workers and an increased incidence of occupational illnesses. Older construction workers also experience a high prevalence of reduced lung function (Dement et al., 2017) and hearing loss (Dement et al., 2018). The incidence of musculoskeletal pain experienced by construction workers



also increases steadily with age (Hoonakker & van Duivenbooden, 2010). In the USA, 40% of construction workers over the age of 50 are reported to experience chronic back pain (Dong et al., 2012). Turner and Lingard (2020) report increasing incidence of bodily pain among Australian construction workers as they age. When this pain is work-related it is associated with higher levels of self-reported symptoms of depression and anxiety (Turner & Lingard, 2020). Ageing is also associated with cognitive decline characterised by a reduction in processing speed, reasoning, memory and executive functions (Deary et al., 2009). This can impact workers' experiences of particular job characteristics. For example, Kanfer and Ackeman (2004) report that older workers experience stress in jobs that involve intensive short-term processing of information due to age-related changes in cognitive function. Compared to younger workers, older workers are more adversely affected by psychosocial job demands, including working under time pressure, a lack of employment security, and concerns about unfavourable changes in the work environment (De Zwart et al., 1999). A Dutch study of manual/non-managerial construction workers found high levels of burnout among older workers contributed to early retirement (Oude Hengel et al., 2012).

In comparison with older workers, young workers (frequently defined as workers under the age of 25) are more prone to workplace safety incidents and injuries. This is particularly the case for young male workers (Salminen, 2004; Breslin & Smith, 2005) and those in manual/unskilled jobs (Breslin et al., 2007). Young workers are often exposed to work-related risks. For example, in Australia, holding other factors constant (including working hours, employment type, industry, occupation and whether or not a job involves nightshift), workers aged between 15 and 24 are exposed to 30% more workplace hazards than workers aged 55 or over. Turner et al. (2015) also report young workers to have low levels of health and safety voice behaviour, indicating a reluctance to speak up when they experience dangerous or stressful work situations. Young Australian construction workers are also reported to experience high levels of psychological distress when levels are benchmarked against national normative data (Pidd et al. 2017). This is often associated with bullying and harassment in the workplace (McCormack et al. 2013). Critically, Australian construction apprentices are two and a half times more likely to suicide than other young men of their age (Mates in Construction, 2016).

Although musculoskeletal pain is more prevalent in older workers, research suggests that work-related musculoskeletal injury also affects young workers (Beers & Greaves, 2015). Indeed, a study of construction apprentices found that they experience high rates of musculoskeletal injury linked to poor lifting and manual handling practices. Thus, unsafe and unhealthy work practices that contribute to bodily pain can begin early in the working lives of young workers (Merlino et al. 2003). Hoonakker and van Duivenbooden (2010) also observe that construction workers differ from workers in other industries because they start working at a relatively early age (as young as 15 or 16), such that by the time they are 65 they will have worked for 50 years. In this context, cumulative exposure to adverse work conditions may have particularly significant effects on construction workers' health and wellbeing, both mental and physical.

Aim

The research presented in this paper sought to examine psychosocial job quality factors impacting the mental health of construction workers in different age brackets, i.e. young workers, middle-aged workers and older workers. Specific objectives were to: (i) identify job quality characteristics that significantly predict mental health in each age group, (ii) compare and contrast the determinants of mental health among workers in different age groups, and (iii) consider the implications of any observed similarities/differences for the development of strategies to support healthy ageing in the construction industry.

Before describing the methods and presenting the results of the research we briefly summarise the literature relating to job quality and workers' health and explain the application of a life span developmental perspective in our research.



Job quality, health and wellbeing

Employment is usually associated with having better health. However, it is increasingly acknowledged that the quality of work is important for good health (Findlay et al. 2013). Indeed, Butterworth et al. (2013) report that the prevalence of common mental disorders is similar among the unemployed to those in poor quality jobs, suggesting that poor quality work is as bad for mental health as unemployment.

Job quality has been defined as ‘those sets of work features which foster the wellbeing of the worker.’ (Strazdins et al., 2010, p. 2052). While there is no universally agreed set of components for job quality, it is often conceptualised as a multi-dimensional construct reflecting the presence or absence of psychosocial risk factors in a particular job. Drawing on the Job-Demands-Control and Effort-Reward Imbalance theories, aspects of job quality that are frequently considered by researchers include job demands, job control, and fair pay (Butterworth et al., 2011; 2013). In addition, job security has been identified as a characteristic of work of particular relevance to health (Strazdins et al., 2004).

Psychosocial job quality is reported to be a predictor of sickness absence, with people reporting one, two or more than two risk factors (low job security, low job control, high job demands and complexity and a perception of unfair pay) taking 26%, 28% and 58% more sickness absence than people experiencing optimal job conditions respectively (Milner et al., 2015). Research drawing on large-scale cohort studies in Australia and the UK also reveals that when people move into jobs in which they are exposed to psychosocial adversity, their levels of self-reported mental health problems (Butterworth et al., 2011) and diagnosed common mental disorders (Butterworth et al., 2013) also increase. Importantly, the relationship between job quality and health appears to operate differently with respect to physical and mental health. Although people working in poor quality jobs experience poor physical and poor mental health, Butterworth et al. (2011) found that moving into a poor quality job was associated with a subsequent deterioration in mental but not physical health. Butterworth et al. (2011) conclude that people in poor physical health are more likely to self-select into poor quality jobs.

Of relevance to this study, the health effects associated with remaining in employment as workers age has been linked to job quality. In a study of Australian workers aged 50-59, job quality was linked to changes in mental health, physical functioning and physical activity over time. Compared to voluntary retirees, whose mental health increased between baseline and follow-up waves of data collection, older workers in poor quality jobs experienced a significant deterioration in mental health (Welsh et al. 2016). Older workers who worked in poor quality jobs also experienced significantly greater deterioration in physical functioning and physical activity compared to voluntary retirees. Importantly Welsh et al. (2016) report a linear trend between length of exposure to poor quality work and the likelihood of adverse health outcomes in older workers. Job quality has also been reported to impact mental health across generations, with children of mothers and fathers in poor quality jobs showing significantly higher incidence of emotional and behavioural difficulties than other children, even when controlling for income, parents’ education, family structure and work hours (Strazdins et al. 2010).

A lifespan developmental theoretical perspective

The present study is underpinned by a lifespan developmental theoretical perspective, which seeks to explain the individuals’ life experiences by studying the sequence of interactions between individual (biological and psychological) and contextual (social and environmental) determinants of development (Zacher et al., 2019). According to Zacher et al. (2019), a lifespan developmental perspective does not comprise a single theory but, rather, is a broad way of thinking (meta-theory) about human development from childhood to maturity. A lifespan developmental perspective has informed the development of numerous mid-range theories about how people can age successfully in ways that minimise their loss of functionality (both physical and cognitive) and maximise subjective (e.g. life and work satisfaction) and objective (e.g. mental health and physical functioning) life outcomes.



More recently, the concept of successful ageing has been re-focused to consider the determinants of subjective and objective work-related outcomes that are valued and important to employees and their organizations (Olson & Schultz, 2019). Age is regarded as a key antecedent of these outcomes, but a variety of personal and contextual variables is also believed to influence workers' experiences. In the case of health outcomes, these variables may be more important than chronological age. Understanding the factors that interplay to shape important outcomes, including workers' health, is therefore an important first step to developing strategies that enable successful ageing at work.

Changes to workers' physical, cognitive, emotional and motivational resources that occur with age may mean that the individual resources that workers bring to a job no longer fit well with their job demands (Schmitt & Unger, 2019). For example, Kanfer and Ackerman (2004) suggest older workers experience stress in jobs that involve intensive short-term processing of information due to age-related changes in cognitive function, while Truxillo et al. (2012) suggest that deterioration of physical capacity, fitness and sensory capabilities can contribute to occupational injuries in workers whose jobs require these capabilities.

Kooij (2015) developed a theoretical position on successful ageing at work that focused on employees' proactive behaviours to maintain their person-job fit, for example, by maintaining their physical fitness and work ability. Baltes and Baltes (1990) also suggest that workers engage in adaptive behaviour to trade-off the impacts of resource depletion associated with ageing and maintain an effective fit with their job demands. Thus, older workers can: (i) actively choose the life and work goals that they will pursue to avoid stressful situations (selection); (ii) seek to attain, develop and use particular resources to help them achieve their goals (optimization); and apply strategies to make up for resource losses or the limitations they may experience that are associated with ageing (compensation) (Schmitt & Unger, 2019).

The research presented in this paper provides preliminary evidence that a lifespan developmental perspective is useful to understand the experiences of construction workers in different age groups.

RESEARCH METHODOLOGY AND METHODS

The study employed a quantitative approach by analysing the association between psychosocial job quality factors and the mental health of construction workers. The quantitative approach is in line with the "positivist" worldview, using deductive reasoning to develop knowledge based on observation and measurement (Cresswell, 2014).

Data and sampling

The study used an existing (secondary) dataset. Data was extracted from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The dataset is accessible to researchers on a subscription basis. HILDA is a longitudinal, nationally representative study of Australian households. Data is collected in annual waves from over 13,000 individuals within over 7,000 Australian households. Data is collected using a combination of face-to-face interviews and self-completion questionnaires and includes a range of social, demographic, health, and economic factors. For the current study, data from the latest 10 waves of the survey which are available (years 2009-2018) was used. The HILDA dataset was searched to identify participants working in the construction industry (based on the ANZSIC 2006 industry classification code). Further, manual/non-managerial workers (technicians and trades workers, machinery operators and drivers, and labourers) were identified based on ANZSCO 2006 occupation classification codes. Participants aged 18 and over were included in the sample. Due to the longitudinal nature of the study, individuals who had only participated in one wave of the survey were excluded from the sample. Cases with missing data were excluded on an analysis-by-analysis basis. The final dataset included 4850 responses from 1221 individuals. There were 1186 males and



35 females. Four hundred and thirty respondents were younger than 24 years old, 513 respondents were aged between 25-45 and 278 respondents were older than 45.

Measures

Mental health was measured using a subscale of the SF-36 general health survey, which has been previously validated in the HILDA survey (see Butterworth and Crosier, 2004). The mental health scale includes five items and measures how often in the past four weeks respondents experienced positive emotions (e.g. feeling happy or calm) and negative emotions (e.g. feeling nervous or down). In the HILDA dataset, the mental health scale is transformed, based on the procedure suggested by Ware et al. (2000), to reflect a 1-100 range. A higher score indicates better mental health.

Job quality was measured using four components suggested by Butterworth et al. (2011), including: (i) job demands and complexity (four items, e.g. My job is complex and difficult; My job often requires me to learn new skills); (ii) job control (three items, e.g. I have a lot of freedom to decide how I do my own work); (iii) job security (three items, e.g. I have a secure future in my job), and (iv) effort-reward fairness (one item: I get paid fairly for the things I do in my job). Participants indicated their agreement with each item on a 7-point Likert response format ranging from 1 (strongly disagree) to 7 (strongly agree). The scores for negative items were reversed. The scores were averaged across all items for each component to reflect a single score for each aspect of job quality.

Control variables

Age: Participants' age in the first wave of the survey (2009) was included in the analysis as a control variable. In addition, to compare relationships between age groups, participants were divided into three age groups: younger than 24; between 25 and 45; and older than 45. These have been referred to as the exploration, establishment and maintenance stages of a working lifespan (Schmitt & Unger, 2019). Household structure: Following Milner et al. (2017), participants' household structure was categorised into: couple; couple with children; single parent; single person; other. Education: The highest education level of each participant was captured as a categorical variable reflecting: 1) Year 11 and below; 2) Year 12; 3) Certificate III or IV; 4) Advanced diploma or diploma; 5) Bachelor or honours; 6) Graduate diploma; Graduate certificate; 7) Postgraduate study - masters or doctorate. Household income: In the HILDA dataset, the gross income band of participants' households for the previous financial year in each wave is captured using 13 categories: 1) negative or zero; 2) \$1-\$9999; 3) \$10,000 - \$19,999...12) \$150,000 - \$199,999; 13) \$200,000 or more. Other control variables included gender, years worked in current occupation, having a disability or long-term health condition, and whether participants were caring for another person due to a health condition, or because they are elderly or had a disability requiring care.

Statistical analysis

Random-intercept linear regression models were used to examine the association between the four aspects of job quality and mental health. These models accounted for two-levels, i.e. responses were clustered within individuals, to account for correlated responses for each individual over the waves. The models fitted a fixed regression slope for mental health, reflecting the average change of mental health scores over time (i.e. within-person changes over the survey waves), while allowing the intercept to vary between respondents to reflect the different initial mental health states of individuals. Initially three models were fitted (one for each age group) regressing mental health on the four components of job quality (see Table 1). Subsequently, three additional regression models were fitted controlling for the covariates described above (see Table 2).

RESULTS

Table 1 presents the results of the first set of regression models testing the association between mental health and the four components of job quality in the three age groups. The table lists

coefficient values and their corresponding standard errors (in brackets). Separate regression models were fitted for each age group.

There was a positive and significant association between mental health and job security in all age groups, and the association was stronger among younger participants. Perceived fairness of effort and reward (pay) was positively and significantly associated with mental health in young (18-24) and middle-aged (25-45) workers. On the other hand, the associations between mental health and job control and job demands and complexity were statistically significant in middle-aged (25-45) and older (>45) workers, with a positive association between job control and mental health and a negative association between job demands and complexity and mental health.

Table 1: Testing the association between mental health and the four components of job quality

	Age group 1 (18-24)	Age group 2 (25-45)	Age group 3 (>45)
Job demands and complexity	-.107 ^a (.399 ^b)	-.616(.311)*	-1.696(.404)**
Job control	.013(.285)	.452(.221)*	1.034(.298)**
Job security	2.866(.321)**	1.875(.246)**	1.707(.298)**
Effort-reward fairness	.624(.241)**	.731(.192)**	.335(.244)

* p<0.05; ** p<0.01; a: coefficient value; b: standard error

Table 2: The association between mental health and job quality in the presence of control variables

	Age group 1 (18-24)	Age group 2 (25-45)	Age group 3 (>45)
Job demands and complexity	-.294 ^a (.452 ^b)	-.552(.331)	-1.618(.415)**
Job control	.372(.337)	.12(.23)	.714(.310)*
Job security	2.956(.360)**	2.036(.255)**	1.445(.310)**
Effort-reward fairness	.454(.274)	.573(.200)	.154(.25)
Age (at baseline)	-.0421(.328)	.192(.090)*	.334(.118)**
Years worked in current occupation	-.087(.153)	-.044(.047)	.015(.037)
Average work hours per week	-.052(.047)	.004(.033)	.067(.035)
Disability/long-term health condition			
No	0 (Ref)	0 (Ref)	0 (Ref)
Yes	-1.066(1.449)	-2.475(.843)**	-3.173(.882)**
Household structure			
Couple	0 (Ref)	0 (Ref)	0 (Ref)
Couple with children	-1.657(1.307)	-1.161(.789)	-1.040(1.334)
Single parent	18.205(12.9)	-2.524(2.489)	-11.503(2.38)**
Single person	-2.793(1.444)	-5.275(1.274)**	-4.397(1.519)**
Other	.646(1.229)	-7.894(1.813)**	-3.031(3.284)
Gender			
Male	0 (Ref)	0 (Ref)	0 (Ref)
Female	-2.213(4.301)	-3.639(3.519)	-6.250(4.857)
Household income band	-.350(.232)	.002(1.805)	.0132(.208)
Education	-.127(.589)	.983(.497)*	.225(.52)
Caring for another person	1.139(4.243)	-.556(1.805)	-1.100(1.917)
Satisfaction with work-life balance	.082(.261)	.928(.193)**	.988(.27)**

* p<0.05; ** p<0.01; a: coefficient value; b: standard error

A second set of regression models was fitted to test the associations identified in Table 1, while controlling for other confounders. The results are presented in Table 2. While the positive association between mental health and job security remained significant for all age groups, the positive association between job control and mental health was only statistically significant for older workers.



Similarly, higher job demands and complexity was associated with poorer mental health among the older workers, but not among workers below the age of 45. Considering the other variables, having a disability or health condition was (statistically) significantly associated with poorer mental health in middle-aged and older workers but not among younger workers. In addition, being a single person was a statistically significant predictor of poor mental health for middle-aged and older workers, but not for younger workers. Satisfaction with work-life balance was also positively and significantly associated with mental health in workers older than 25, but not in those below the age of 25.

Further analysis, by entering the control variables into the models in steps, revealed that for middle-aged workers (25-45), the relationships between mental health and job control and mental health and job demands and complexity were mediated through workers' satisfaction with their work-life balance. That is, when work-life satisfaction was included in the model, the effects (coefficients) of job control and job demands and complexity were no longer significant, and their magnitude was reduced. In turn, work-life satisfaction was significantly related to mental health.

DISCUSSION

The link between job quality and mental health

Older workers' experiences of health, safety and wellbeing have previously been attributed to both individual (e.g. biological and behavioural) and contextual factors (organisational and job-related characteristics) (Truxillo et al 2015). This research revealed that the mental health of manual/non-managerial construction workers in Australia is influenced by various psychosocial job quality factors. In this respect, our findings are consistent with previous research that has focused on contextual/environmental determinants of health (Marmot, 2005). However, the results also show that the impact of job quality on the mental health of construction workers is nuanced. Aspects of psychosocial job quality that are predictive of mental health vary between workers in different age groups. This is important information as the productivity of the construction industry's workforce requires organizations to attract young workers, as well as to better retain older workers. The latter point is salient given the ageing population in Australia and the resulting increase in the proportion of construction workers over the age of 45.

Experiences of different age groups

Overall, the results indicate a positive association between job security and mental health in all age groups, while, after controlling for other confounders and contextual factors, job control and job demands and complexity were significantly associated with mental health only in the older age group (workers older than 45).

As a project-based industry, job security is a particular concern as continued employment depends upon successfully winning work in a highly competitive commercial environment. Precarious employment has been linked to health in various ways. It can increase workers' exposure to hazardous working conditions (including physical and psychosocial risks) while also contributing to material deprivation relating to income, wealth and savings, housing quality, superannuation etc. (Benach et al., 2016). The links between job insecurity and mental health across all age groups found in the current study suggest that employment policies and practices should be carefully considered to reduce the adverse mental health outcomes that flexible employment practices can create.

After controlling for confounding variables, job control and demands and complexity remained significant predictors of mental health for older workers. This finding is somewhat consistent with previous research that older workers are more adversely affected by working under time pressure (De Zwart et al., 1999). Previous research (Ng & Feldman, 2015) has found age-related differences in the relationships between job autonomy (control) and work-related outcomes. However, they did not specifically focus on workers' health.

The finding that the effects of job demands and complexity, job control and effort-reward fairness were not significant after controlling for confounding variables, and that the relationships



between these job quality components and mental health were mediated by satisfaction with work-life balance among middle-aged workers is also noteworthy. Workers in this age group (25-45) may have more significant caring responsibilities for dependent children. Previous research has linked parental demands during mid-life to poor health (Evandrou et al., 2003). This may be one explanation for the significant mediation effect of satisfaction with work-life balance in middle-age workers that was not found in other age groups.

Supports for healthy ageing in the construction industry

The findings have important implications for the protection of mental health in the construction industry because, just as poor quality work has a negative impact on mental health, it is possible that improving the quality of work can have a positive impact on mental health among manual/non-managerial workers. However, the relationships between various components of psychosocial job quality and mental health are not 'age neutral.' The lifespan developmental theoretical perspective acknowledges that workers' experiences of job characteristics are shaped - at least to some extent - by their age. Thus, it is useful to draw on a lifespan perspective in considering the types of workplace interventions that could minimise the harm of psychosocial risk factors and promote mental health among workers in different age groups.

Our results suggest that workers in all groups would likely benefit from policies designed to improve job security. However, interventions targeting middle-aged and older workers may need to focus on other job quality characteristics that predicted mental health in their age groups. For example, middle-aged workers may benefit from more flexible work practices that would help them to achieve a balance between their work and non-work lives. On the other hand, older workers may benefit from strategies designed to reduce job demands and complexity and/or increase their control over how their work is done.

Griffiths et al. (2009) similarly suggest that providing older workers with greater control over the pace at which they work, the level of their involvement in work, the length and timing of shifts worked and work-rest schedules is likely to be beneficial for their health, workability and workforce participation. Griffiths et al. (2009) also recommend reducing job demands and complexity to ensure tasks are age-appropriate and reduce the need to work overtime, night shifts etc, that are known to have a negative influence on the health of older manual/non-managerial workers (Costa & Sartori, 2007).

CONCLUSION

Our findings support the link between job quality and mental health among manual/non-managerial construction workers. The results also highlight the usefulness of applying a lifespan theoretical perspective to understand age-related differences in the way that psychosocial risk factors in the work context are related to mental health. The findings suggest that work design and workplace mental health interventions should not be considered to be 'age-free' because the mental health of young, middle-aged and older construction workers is associated with different psychosocial job quality factors.

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Improving Mental Health and Safety in the Construction Industry: A Study in Australia

Carol K. H. Hon

Queensland University of Technology, Australia

Correspondence: carol.hon@qut.edu.au

ABSTRACT

Many construction workers have poor mental health conditions. In Australia, construction workers died by suicide six times more than they were killed by accidents in construction sites. While there are many factors leading to suicide, a prolonged exposure to psychosocial hazards and their risks in the workplace adversely affects mental health of the construction workforce. Research on psychosocial risks in the construction industry has been very limited.

Many existing studies are qualitative and overlook the interdependencies of psychosocial risks and their impacts on mental health of the construction workforce. This lack of information means that mental health intervention strategies may not be as effective as they could be. To fill this gap, the author is undertaking a research project to improve mental health and safety of the Australian construction industry using a Bayesian network and agent-based modelling approach. This paper aims to outline the research framework and share the latest progress and preliminary findings of the research project. Prevalent psychosocial hazards in the construction industry were identified through interviews. Strategies to manage psychosocial hazards and improve mental health of construction practitioners were proposed. While the research described in this paper is being conducted in Australia, comparative research can be done in other countries where the construction workforce is exposed to similar psychosocial hazards with poor mental health. This paper would provide insights to researchers who are interested in mental health and safety in the construction industry.

KEYWORDS: Mental health and wellbeing, health and safety, construction

INTRODUCTION

The construction industry in Australia employed 9.6% of the workforce in Australia between 2019 and 2020 (Australian Construction Industry Forum, 2021). Women accounted for only about 15% of all the employees in the Australian construction industry (Construction Skills Queensland, 2021). The construction industry is male dominated, physically demanding and has a tough guy culture. Jobs in the construction industry tend to be temporary, transient and project-based. Some construction workers work in isolation or remote construction sites. Work environments have various physical hazards, and many job tasks involve high risks. Construction workers are highly susceptible to psychosocial risks that affect their mental health and wellbeing.

Mental health of the construction workforce deserves serious attention across the globe. In the UK, skilled tradies accounted for 13.2% of the suicides reported between 2011 and 2015 but construction only employed 7% of the total workforce in the UK (Office of National Statistics, 2017). The U.S. construction industry's suicide rate was 53.3 per 100,000 population in 2012 whereas the national average suicide rate was 12.54 per 100,000 people in 2012 (McIntosh et al., 2016). Construction



workers in Australia were six times more likely to kill themselves than they die in construction accidents (Milner, 2016). According to Doran and Ling (2015), approximately AUD 1.57 billion was lost each year due to suicides in the Australian construction industry.

Although mental health of the construction workers has emerged to be an important health and safety issue in the construction industry, only limited research has been conducted (Milner and Law, 2017), and a comprehensive assessment of the psychosocial factors affecting the mental health of construction workers has been lacking. There is an urgent need for the systematic identification of the psychosocial risk factors involved so they can be better managed to improve health and safety standards. Moreover, existing research into psychosocial risks is mainly qualitative (e.g. Colquhoun et al, 2016), or employs basic descriptive or inferential statistics (e.g. Jimmieson et al., 2016), and fails to capture the interdependencies between psychosocial risk factors during the project lifecycle quantitatively. This lack of information means that mental health intervention strategies may not be as effective as they could be. In particular, the current strategies of suicide prevention programs mainly focus on the sharp end, (e.g. identifying and helping those who are struggling) but more attention should be given to the blunt end of the problem (e.g. identifying the sources of psychosocial risks) to fundamentally addressing the industry's mental health and safety problems. Evidence-based strategies for addressing the psychosocial risks of construction projects are lacking and more is needed to deliver the breakthrough required to deal with this national challenge. Psychosocial risk assessment tools are too general and do not address the needs of the construction industry.

This research will fill the knowledge gap by identifying the psychosocial risks involved in construction projects and their causes by developing a Bayesian network model to determine the interdependencies of fundamental psychosocial risk factors. The research will evaluate the effectiveness of the model, and provide evidence-based strategies to address these risks. The findings will contribute to the Mental Health Action Plan (2016-2020) of the Workplace Health and Safety Queensland (2017) to improve the management of psychosocial risks and health and safety performance.

This paper aims to outline the research framework and share the latest progress and preliminary findings of the research project funded by the Australian Research Council. The primary goal of the research project is to develop a Bayesian network model to analyse the psychosocial risk factors in the industry and employ agent-based modelling simulation to develop effective strategies for improving mental health and safety. The specific objectives are:

Objective 1: Identify the psychosocial risk factors and their interdependencies in the construction industry.

Objective 2: Develop a Bayesian network model to manage the psychosocial risks involved.

Objective 3: Evaluate the effectiveness of the Bayesian network model to manage psychosocial risks.

Objective 4: Derive evidence-based strategies for improving mental health and safety in the industry.

RESEARCH FRAMEWORK

This project will investigate the interdependencies of psychosocial risks factors involved in construction work and their impact on mental health and safety. The ultimate goal is to develop strategies for improving the mental health and safety of the construction workforce. Figure 1 provides a basic overview of the research framework:

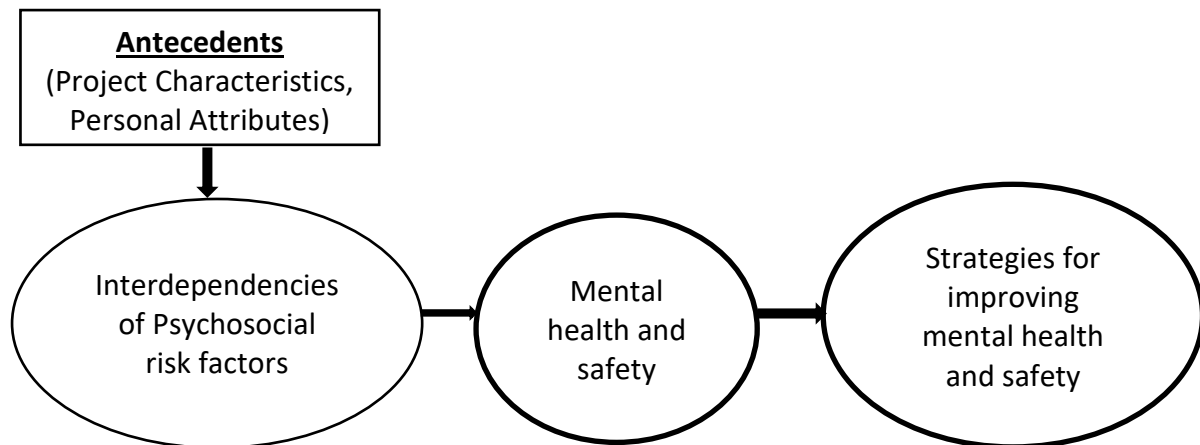


Figure 1. Research framework.

Stage 1: Causal mapping to produce influence diagrams of psychosocial risk factors

Objective 1: Identify the psychosocial risk factors and their interdependencies in the construction industry.

The research will utilise a multidisciplinary approach based on cognitive and causal mapping techniques that are widely used for capturing organisational “sense-making”, that is, the process by which people give meaning to their experiences (Weick, 1995; Weick et al., 2005). Interviews will be conducted with different industry participants involved in a construction project, such as project managers, supervisors, foremen, and construction workers, to identify the typical factors leading to psychosocial risks in construction projects and their impact on the workers’ health and safety. This will be the starting point for analysing psychosocial risks, project characteristics, and activities causing psychosocial risks, and health and safety performance. Preliminary influence diagrams will be developed by identifying the key factors for managing psychosocial risks.

The research will adopt the group-based approach for causal mapping used by Ackermann and Eden (2005) to investigate the failure of complex projects. Interviewees will be invited to participate in a sense-making workshop, a process that ensures multiple perspectives are obtained to produce a balanced and comprehensive set of variables and their inter-relationships. Research participants will be sourced from QUT’s Project Management Academy industry partners and their respective industry networks.

The first step in the sense-making process involves identifying variables adjustable to the emergent working environment. A networked computer-based group support system tool (Group Explorer) will be used to provide the preliminary influence diagram (derived from the interviews) to the participants (Ackermann and Eden, 2005). Participants will be invited to review the preliminary influence diagram, including the variables, their interactions, and explanations of the linkages involved, and will be able to revise and restructure the diagrams based on their own personal understanding of the industry. Participants will use their knowledge to establish a preliminarily set of values for the variables to construct a Bayesian network model.

The outcome of stage 1 will be an influence diagram of psychosocial risk factors. This is innovative because of the involvement of multidisciplinary industry practitioners in producing the influence diagram containing the interdependencies between the psychosocial risk factors.

Stage 2: Development of a psychosocial risks model

Objective 2: Develop a Bayesian network model to manage the psychosocial risks involved.

The Bayesian network approach will be adopted in this research to develop a Bayesian model by further analysing the variables identified in Stage 1. The Bayesian network has been employed for analysing risks in complex socio-technical environments. It helps to identify the most important risks, and supports decision-making, and it is particularly useful in complex dynamic modelling, accounting for a large number of independent and dependent probability parameters (Hanninen, 2014). Bayesian networks can cope with uncertainties in model building in the form of probabilities, treating uncertainties explicitly and offering a means for their reduction. The flexibility of constructing a Bayesian network model with both expert knowledge data and machine learning means that the model parameters can be updated to reflect reality better when more data has been collected (Hanninen, 2014)

A questionnaire survey will be conducted with major contractors and subcontractors. The survey will be administered to their project management team, site supervisory staff, and workers as they are the ones directly experiencing the psychosocial risk factors involved. Data will be collected for estimating the parameters of the Bayesian network model using a suitable learning algorithm. The respondents will be asked to provide values and indicate the direction of the relationships between the factors leading to psychosocial risks and affecting the stakeholders' health and safety. Approximately 400 completed questionnaires will be targeted. The parameters of the Bayesian network model will be verified and modified with data from the survey. The expectation-maximization (E-M) algorithm is considered appropriate to use with the survey data for Bayesian network parameter learning (Zhao et al., 2012). The E-M algorithm is "an iterative method for finding the maximum likelihood or maximum posteriori estimates of parameters from an incomplete dataset" (Chan et al., 2020, p.6)

The outcome of Stage 2 will be a Bayesian network model for managing psychosocial risks in the industry. This approach will allow a more accurate identification of risk factors and reveal findings that would not otherwise be identifiable from basic descriptive statistics.

Stage 3: Scenario simulation to evaluate the effectiveness of the strategies in mitigating psychosocial risks and improving the health and safety of stakeholders

Objective 3: Evaluate the effectiveness of the Bayesian network model to manage psychosocial risks.

Construction sites are complex social systems that are nonlinear and cannot be predicted analytically, and agent-based modelling (ABM) has been applied previously in construction research (Lu et al., 2016; Marzouk and Ali, 2013; Palaniappan et al., 2004; Sawhney et al., 2003) for the computer simulation of such nonlinear systems. ABM can model human behaviours in a bottom-up approach with repetitive decentralized interactions to resemble complex behaviours, such as bullying and peer pressure, in a social system (Lu et al., 2016; Palaniappan et al., 2004). This innovative evaluation will significantly enhance the usefulness of the model in creating strategies informed by computational stimulation findings.

The agents are project management, site supervisory staff, and workers. The environment will be a simulated construction site. Their behaviours will be described using simple rules, and conditional probabilities from Bayesian network model. The agents will have unique probabilities to make decisions based on the perceived environment at certain point in time and space. "What if" scenario simulations will be conducted to evaluate the effectiveness of the model in mitigating psychosocial



risks and improving health and safety. Spatially-explicit experiment simulations will be generated for scenarios set in different phases of construction projects with different project characteristics, for strategies derived from the Bayesian network model, to understand the impact different strategies might have on the whole system.

The outcome of Stage 3 will be the quantification of the effectiveness of the strategies in mitigating psychosocial risks and improving the health and safety of the construction workforce. This approach is innovative because it allows the effect of the proposed psychosocial risk management strategies on mental health to be more precisely predicted.

Stage 4: Formulation of strategies for improving mental health and safety in the Australian construction industry

Objective 4: Derive evidence-based strategies for improving mental health and safety in the industry.

The Bayesian network model formed in Stage 2 and agent-based modelling simulation results from Stage 3 will be presented to the interviewees who participated in Stage 1. They will be invited to participate in focus group meetings to evaluate the usefulness of the model and to develop strategies for improving mental health and safety of the industry. This focus group will be used as an opportunity to:

- consider the potential usefulness of the Bayesian network model for deployment in Australia and the international context;
- develop strategies for reducing psychosocial risks and improving mental health and safety with reference to the results of the Bayesian network model and agent-based modelling simulations; and
- develop guidelines for adopting the mental health and safety strategies in the industry.

The outcomes of Stage 4 include strategies for reducing the psychosocial risks of the construction workforce and guidelines for adopting those strategies. This new approach is innovative because the strategies for improving mental health and safety will be derived from mathematical modelling and simulation and validated by the focus group meetings.

PROJECT PROGRESS AND PRELIMINARY FINDINGS

The project commenced in Jun 2019 and is half-way through the project duration. A meta-analysis of the relationship between psychosocial hazards and mental health in the construction industry was conducted (Sun et al., 2021). The project is currently conducting semi-structured interviews to identify the psychosocial hazards and their interdependencies. This paper will report some preliminary findings identified from the first ten interviews. Interviews were conducted online via Zoom between March 2020 to July 2020. Interviewees were construction industry practitioners with site-based experience. Interview data were thematically coded.

Table 1: Profile of interviewees.

Interviewee	Job Position	Company	Project Experience	Years of industry experience
I1	Cost planner	Tier 1 contractor	Airport	5 years
I2	Contracts administrator	Tier 3 contractor	Fit outs	5 years



I3	Junior contracts administrator	Tier 2 contractor	Fit outs	2 years
I4	Project manager	Client/ Developer	Student accommodations	7 years
I5	Contracts administrator	Tier 2 contractor	Commercial renovation	9.5 years
I6	Site engineer	Tier 2 contractor	Commercial	16 years
I7	Contracts administrator	Tier 2 contractor	Institutional building	30 years
I8	Self-employed builder	Builder	Residential renovation	45 years
I9	Project manager (Fly-in-fly-out)	Contractor for resources infrastructure construction	LNP processing plant	40 years
I10	Site supervisor	Tier 2 contractor	Commercial	20 years

Findings of the preliminary analysis of the interview data relating to the question “Have you ever experienced any situation in the workplace that affects your psychological health and wellbeing in the past 12 months? Please describe.” are shown below. The psychosocial hazards identified from the interviews were in line with previous literature (e.g. Chan et al., 2020; Tijani et al., 2021). High job demand being the most prevalent psychosocial hazard of the site-based construction workforce.

Table 2: Psychosocial hazards affecting psychosocial health and wellbeing of the interviewees.

Interviewee	Psychosocial hazards affecting psychological health and wellbeing
I1	Long working hours, lack of work-life balance, low job control, away from partner
I2	Work overload, long working hours, shift work, low job resources, demanding client
I3	Poor relationship with supervisor
I4	Emotional demand
I5	Long working hours, high cognitive demand, high emotional demand
I6	Long working hours, lack of work-life balance, bullying, low reward and recognition, work in isolation
I7	Work overload, long working hours, low job resources
I8	Financial stress, legal dispute, demanding client
I9	COVID-19, job insecurity, interpersonal conflict
I10	Organisational injustice, long working hours, work overload, low job resources

High job demand

Most of the interviewees mentioned about high job demand, in particular *long working hours* and *work overload*. It is common for site level workers to work 12 hours or longer per day and 6 days a week. Most interviewees experienced work overload that they had to take on unplanned ad hoc tasks. This may be due to dynamic project situation on site or key personnel left the project without replacement.



Low job resources

A few interviewees expressed that there were low job resources. They received limited support from their companies to perform new tasks that require a steep learning curve, making them stressful. Project timeframe of some projects are unrealistic and there is insufficient workforce to complete the project in time.

High cognitive demand

High cognitive demand mainly refers to paying full attention to the tasks. Some interviewees, in the Contracts Administrator role, consider their job of high cognitive demand because they deal with financial forecast, and payment etc which had important financial implications.

High emotional demand

Some interviewees experienced high emotional demand of their jobs causing negative impact on their psychological health and wellbeing. This usually happened when they dealt with *demanding client*, or difficult subcontractors for variations and payments.

Interpersonal conflict

Interpersonal conflict most likely occurred with the supervisors. When supervisor do not have good people management and leadership skills, the subordinate's mental health and wellbeing would be greatly affected. Abusing or bullying are also common on site, causing interpersonal conflicts and affects ones' mental health.

Lack of work-life balance

Lack of work-life balance is inter-related with long working hours and work overload. Interviewees with a young family often expressed lack of work-life balance. They had limited time and energy for their family and for leisure activities they want to do. The situation may be even worse for women in construction because they usually take up more family duties than their partners.

Work in isolation

Interviewees mentioned that they felt difficult when were away from their family working in remote construction site. Some trades also work in isolation, such as plumbing and electricians, many of them do not work in a big crew but all by themselves in small jobs.

Job insecurity

Job insecurity was particularly mentioned by interviewee I9. I9, who was a fly-in-fly-out project manager had to demobilize over 600 workers when the project was stopped due to COVID-19. I9 emphasised that construction industry is project-based, even permanent worker's employments would depend on the projects awarded to the company. To I9, the greatest source of stress comes from job insecurity.

CONCLUSIONS

Mental health of the construction workforce is an important occupation health and safety issue in the construction industry across the globe. This paper outlined the research framework and reported preliminary interview findings of the ongoing research project at Queensland University of Technology. Preliminary findings show that psychosocial hazards are prevalent in the construction industry. Strategies to manage psychosocial hazards and their impacts on the mental health of the construction workforce should be promulgated by the industry, government and mental health supporting organizations. While this research is being conducted in Australia, the same methodology



can be extrapolated to other countries such as the United States and the United Kingdom where the construction workforce is also exposed to prolonged psychosocial hazards. It is anticipated that COVID-19 has attenuated the level of psychosocial hazards in the construction industry. It is high time addressing psychosocial risks in the construction industry to create a psychologically healthy and safe environment for our construction workforce. Future research can be extended this study to the United States and the United Kingdom for a comparative study.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest in this paper.

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A Safety leading indicator approach: an exploratory study of the Nigeria construction sector

Isimemen Judith Ejohwomu, David Oloke, Lovelin Obi and Olugbenga Oladinrin

Faculty of Science and Engineering, University of Wolverhampton,

Correspondence: I.J.Ejohwomu@wlv.ac.uk

Abstract

The construction industry assembles the construction space needed for economic activities. However, the construction industry's reactive approach to safety has a negative impact on the image of the sector. The current study seeks to determine the extent to which proactive tools, such as safety leading indicators (SLIs), are utilized in the construction sector. The study adopted the use of qualitative research methods, and data was collected using interviewees and web scraping. The analysis of the collected data showed that the construction industry adopts the use of a reactive approach to safety management. In addition, the construction segment of the oil and gas industry utilizes a different approach to safety management when compared with other segments of the construction industry. The adoption of proactive measures, such as SLIs, could help to address the poor safety performance in the construction industry.

Keywords: Construction, Health and Safety, Nigeria, Safety Leading Indicators, Sentiment Analysis and Topic Modeling

Introduction

The construction industry produces infrastructure that drives the economy. However, there are occupational health and safety (OH & S) risks, which are inherent in construction tasks. In particular, the sector accounts for at least 100,000 fatalities around the world, which is about 30% of all fatal injuries (ILO, 2015). According to Health and Safety Executive (2020), the number of work-related injuries in the UK's construction sector is almost 400% more than the average number in all sectors of the economy. This data suggests that the construction sector has a poor safety record that needs to be improved. Poor safety performance has an impact on outcomes of construction projects (Wanberg et al., 2013; You et al., 2019). Stakeholders need to develop and implement strategies to improve the safety record of the industry for its sustained growth.

Research into safety within the construction management domain has a long history. One of the first published studies that focused on safety in construction industry was reported in a paper by Andriessen (1978). Subsequently, studies based on the systematic review of literature have shown that the number of published studies on construction safety has grown (Antwi-Afari et al., 2019; Xu et al., 2021). This increase could be attributed to the importance of OH & S. To improve safety performance in the construction sector, studies have suggested that there is a need to move away from a reactive towards a more proactive approach to OH & S (Kjellén, 2012; Li et al., 2015). An understanding of Safety Leading Indicators (SLI) is one of the proactive measures used for improving



safety in construction projects (Xu et al., 2021). However, little is still known about the theory of SLI as a core function of safety management systems in developing countries, such as Nigeria.

The purpose of this study is to explore to what extent SLI is being used as a driver for excellent OH&S practices in Nigeria's construction and sector. This goal is achieved by addressing two research questions: (i) What is the perceived role of the regulatory body in the attainment of an excellent OH & S practice in the sector? and (ii) What is the perception of industry actors and users regarding OH & S performance in the construction sector? The findings of the study make several contributions to the literature. First, the study provides insights into how self-regulation and firefighting influence OH & S practice in the construction sector. Second, it shed lights on the perception of stakeholders on state of OH & S in Nigeria's construction sector.

LITERATURE REVIEW

Health and Safety Culture in Nigeria

As shown previously, the safety performance of the construction sector in developed and developing countries is poor. In Nigeria, studies have attributed poor safety performance to lack of legislation (Ogbonna et al., 2016), poor safety culture, lack of management's commitment (Kukoyi and Smallwood, 2017) and "too much focus on cost rather than safety" (Windapo and Jegede, 2013), among others. Similarly, some studies have also shown that top management's commitment play a huge role in safety performance of construction projects. For instance, Jimoh et al. (2020) showed that positive attitude, setting OH & S as an important agenda for meetings and the use of safety considerations to modify business operations are a true reflection of management's commitment to safety. Also, it was revealed that stakeholders tend to prioritize personal safety rather than conducting inspections to enforce OH & S regulations (Tengan and Aigbavboa, 2017; Williams et al., 2018). Taken together, it seems that the practice of OH & S in the Nigerian construction sector is reactive. Due to weak enforcement of safety legislation in Nigeria, it is imperative for stakeholders to at the very least embed self-regulation in their business operations to improve safety performance of construction projects.

Self-Regulation in the Nigerian Construction Industry

The concept of self-regulation is gaining traction in literature emanating from developing countries. In Nigeria, the proposed National Building Code of 2006 is yet to be passed into law (Omeife & Windapo, 2013). Thus, there is no industry specific legislation targeted at improving safety in the construction sector. Even when legislations exist its effectiveness is dependent on enforcement, motivation of supervisors and self-regulation among workers (Hon and Chan, 2014, Dolphin et al., 2021), among other factors. Research shows that contractors, especially foreign-owned companies, adopt the use of OH & S standards that were developed and implemented in their home countries (Idoro 2011; Tanko & Anigbogu 2012). The foregoing seems to suggest that safety performance of Nigerian construction projects is influenced by worker's self-regulation and the nature of the ownership of a construction company.

Self-regulation is adaptable, engages the governed, and provides a sense of belonging. Self-regulation is also a person-centered approach to safety (Dawson et al., 1983; Cheah, 2007). More so, it is geared to business and customer concerns while it addresses different situations. Aside from being an essential regulatory tool, it addresses cost-related concerns and lowers the state's responsibility.



Above all, it has the potential to reach a higher degree of compliance. As a result, it is regarded as more powerful than command and control regulation.

Lagging indicators and the Nigerian construction site

Self-regulation has the potential to improve safety performance in the Nigerian construction industry. However, the effectiveness of self-regulation depends on two factors: technical and motivational (Dawon et al., 1983). Technical factors refer to the possession of knowledge (either gained through training or experience) and resources needed to identify and respond to safety risks (Dawon et al., 1983). Also, motivational factor can be viewed as commitment to embed technical factors into the operations and practice of an entity (personal or company). For instance, the pay for safety scheme, which is implemented in Hong Kong, has been linked to improved commitment to safety (Chan et al., 2010). Despite the evident benefits of self-regulation, previous research (such as, Kukoyi and Smallwood, 2017; Okorie and Adindu, 2020; Ijaola et al., 2021) seems to suggest that majority of activities in small-sized construction companies in Nigeria are carried out under unsafe conditions. Self-regulation may not be quite effective in these companies as the management focuses mainly on profit. In light of this peculiarity, there is a need to look beyond a solely lagging indicator (*reactive*) driven redress and consider a safety leading indicator (*proactive*) approach to behavioral based safety in Nigeria.

Leading indicators and the Nigerian construction site

There are various definitions of the term “SLI”. Alruqi and Hallowell (2019) assert that SLIs can be viewed as the “...measures of the safety management system that correlate with injury rate”. SLIs are viewed as “...precursors to harm that provide early warning signs of potential failure”. According to Xu et al., (2021), SLI are metrics for quantifying “the current performance of a safety management system of a project or firm”. While a variety of definitions exists, the study adopted the use of definition put forward in Xu et al., (2021) who refers to the level of efficiency of a safety management system. In a systematic review of literature reported in Xu et al., (2021), SLI were classified into three categories: “firm level” (organizational commitment, safety auditing, training and orientation), “project level” (client engagement, designer engagement, contractor engagement, supply chain and workforce engagement, safety design, plan for safety, hazard identification and control, safety learning, recognition and reward and site communication) and “group and individual level” (safety climate, worker involvement and competence). The absence of any of these SLIs serves as an early warning indicator showing an increased probability of an accident (Cheung et al., 2020). Therefore, this information ensures that industry stakeholders embed proactive safety practices in the delivery of construction projects.

RESEARCH METHOD

Several research methods have been used to investigate issues relating to safety in the construction sector. The methods used in the previous research include qualitative, quantitative and mixed (Wilkins, 2011; Mohammadi et al., 2018). Also, data collection methods utilized in these studies includes interviews, questionnaires and archival records, among others (Liang et al., 2021; Mohammadi et al., 2018). In this exploratory study, semi-structured interviews and text mining techniques (secondary data) were used to collect the data required for addressing the goal of the study. Qualitative research approach is considered suitable for the current study due to several reasons. First, the interviewees can freely express their views about the subject, which will be impossible to capture when structured research approaches, such as questionnaire survey, are



adopted (Bryman, 2016). This approach provides deep insights and fresh perspective that have not been previously reported in previous research. Second, qualitative research methods are appropriate for addressing underexplored topics (Creswell, 2014). Very little is known about SLI in the context of developing countries, such as Nigeria. Finally, qualitative methods are useful for answering what questions, e.g., “what is Y?”.

As stated previously, data was collected using two methods to achieve data triangulation. This preliminary output reported in this paper is part of an on-going PhD study. The collection of primary data is delayed due to the outbreak of Covid-19. Semi-structured interviews were conducted with two experienced construction professionals. The criteria for selecting the interviewees are: (i) they are actively involved in the delivery of construction projects, (ii) years of experience and (iii) segment of the construction market. For instance, one of the interviewees is employed in the Nigerian construction sector, which is dominated by the international oil companies. The other interviewee works with a local main contractor. This selection is based on the assumption that foreign-owned firms would comply with OH & S standards through self-regulation when compared with local contractors. The interviews lasted for an average of 80 minutes. With the consent of the interviewees, the interviews were recorded. Subsequently, the recordings were transcribed. The transcripts were analysed using thematic analysis.

The internet has become a repository of vast amount of secondary data which is useful for research. Data from Twitter™ was scrapped using Rvest package within the R programming environment. To address research question 2, data (Tweets) which are archived on the internet were collected. Tweets, which are posted by people located in Nigeria, relating to building collapse covering the period between 2018 and 2021 were extracted from Twitter using application programming interface (API). These data contain Tweets by members of the general public (i.e., users) and professionals (industry actors). This data provides information on the perspective of industry actors and users on OH & S practices relating to response to building collapse. The scrapped data was cleaned and analysed using text mining techniques, e.g., bag of words and sentiment analysis. Text mining is a method of choice when analysing large volumes of unstructured text data. This method has been used to uncover the impact of Tweets on stock market price (Karakatsanis et al., 2017; Oliveira et al., 2017). The findings emanating from the analysis of the interview transcripts and text mining are presented in the next section.

RESULTS AND DISCUSSION

The results are in twofold:

1. Social Media Data

Text analytics is an artificial intelligence (AI) tool that uses natural language processing (NLP) to transform free (unstructured) text into, normalized and structured information. The search period (2018 - 2021) is a snapshot into recent social media discourse relating to construction and OH & S regulations. This includes all Tweets within 250km radius in Nigeria. The result was then cleaned before analyzing. The file had 431 rows and 4 columns (date, time, username and tweets). The tweet column contained the discussions around OH & S, governance, regulations, construction and recent building incidents. The scrapped data was representative of three of the six geopolitical regions in Nigeria, namely North Central, South-South and South West. On the surface, the unstructured data seemed not to support the two research questions posed in the introduction. However, when structured using text analytics the following patterns emerged as captured in Figure 1 and Figure 2.

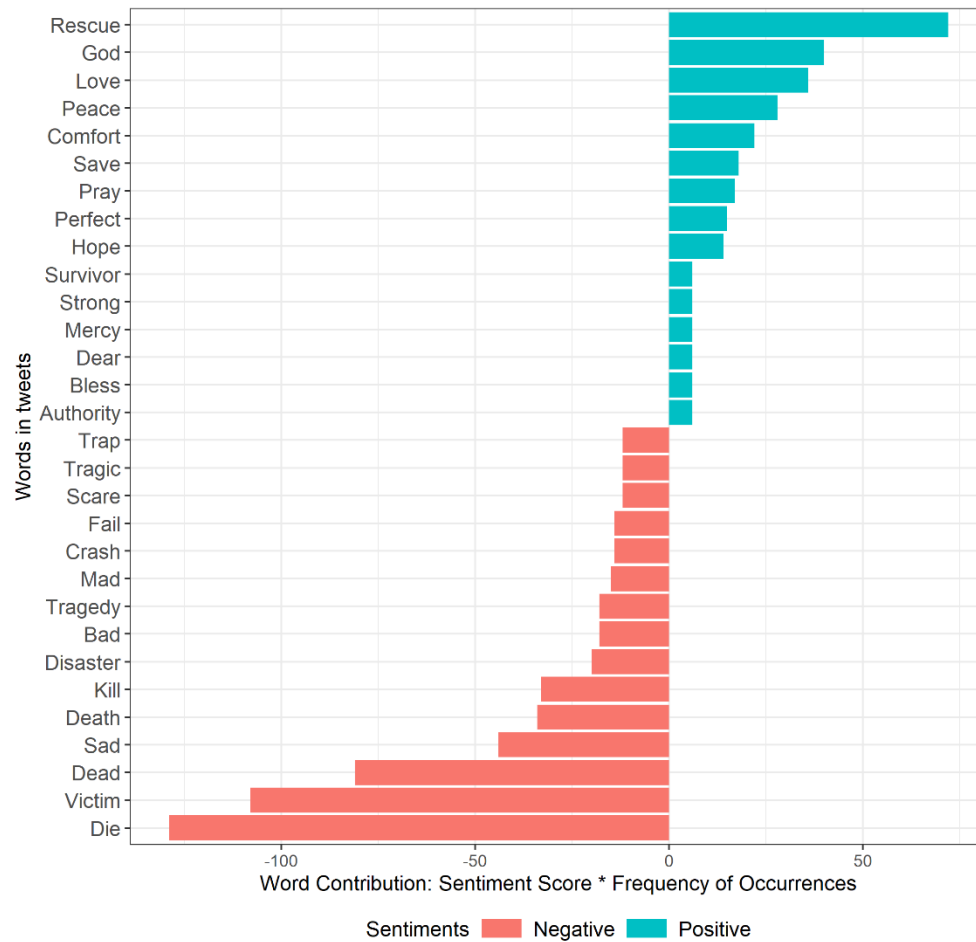


Figure 1: Polar sentiment of top 15 words in data scrapped from Twitter between 2018 - 2021

Figure 1 is a polar sentiment of the top 15 words present in the data. The word contributions are vividly skewed towards negative sentiments, which speak volume of stakeholders' perception of the construction industry and its OH & S standards. Words like "die", "victim" and "dead" which have very high frequency is an indication of the trauma and pain felt by some stakeholders drawn from tweets like *"...woman commits suicide after losing two children in Lagos building collapse."* [Tweet row 113] Notably, the context within which the positive sentiments like "rescue", "God" and "love" were used, is more a function of the emotional impact of the trauma endured by some Nigerians when it comes to their perception of the performance of the construction sector and not how good safety regulation is. For example, this tweet read, *"...every body is sad, government officials are commiserating with the families of victims"*, and there is bewilderment towards the reoccurrence of building collapse *"...every year buildings collapse with many casualties but that is it"*. [Tweet row 130] This particular finding resonates with the argument of previous commentators that majority of activities in small sized construction companies in Nigeria are carried out under unsafe conditions (Okorie and Adindu, 2020; Ijaola et al., 2021).

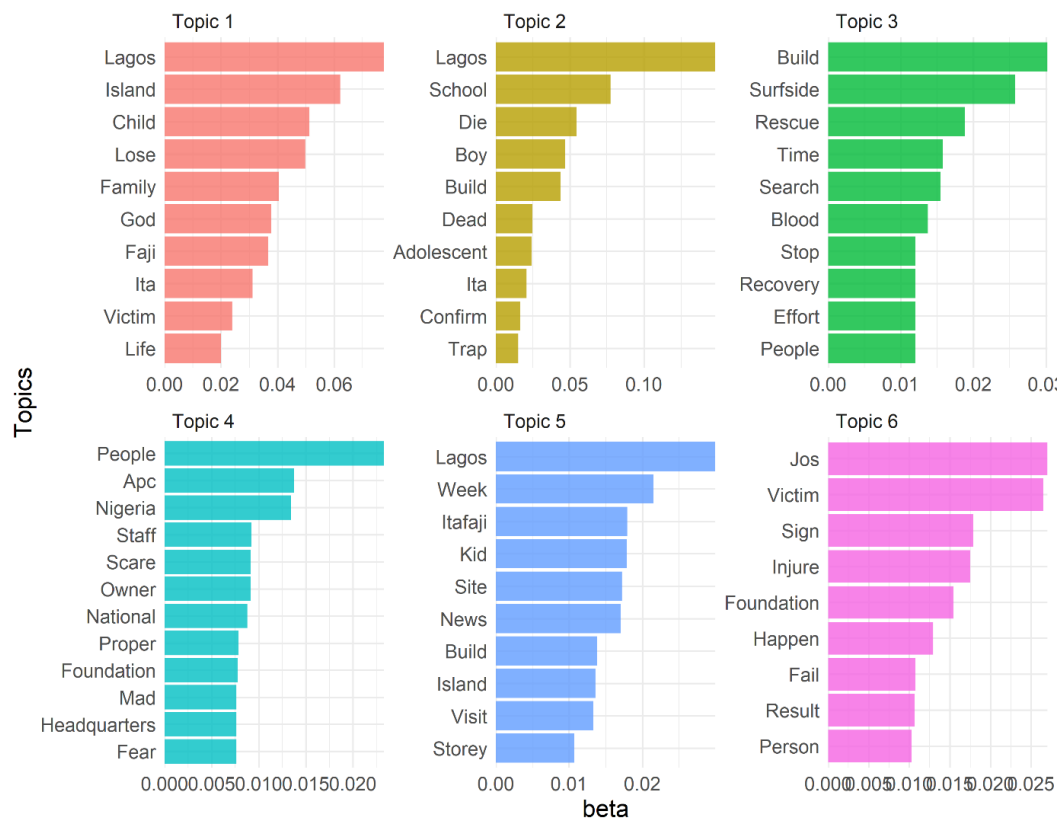


Figure 2: Emergent topic models and their respective beta values

The topic model captured in Figure 2 is an output of natural language processing. This allows for sense making and clustering of the unstructured texts. When combined, the six topics were transposed into three clusters:

1. Building collapses emerged as a cluster. This resonates with the literature as a major cause of injuries and fatalities. The propensity of occurrence is particularly high in poorly regulated sectors with misguided preference of self-regulation.
2. Lagos as a location emerged as a cluster. This city is home to approximately 17 million residents with a population density of around 6,871 residents per square mile. It is the 8th fastest growing city in Africa and generates 25% of Nigeria's GDP (National Bureau of Statistics 2021). This may explain why it emerged as a cluster relative to the states in the three geopolitical regions.
3. The voices of affected and impacted stakeholders also emerged as a cluster. This cluster captures the perception (voices) of a sizeable construction and OH & S stakeholders in Nigeria.

The view of one other tweeter was, *“There is no review of building legislation, the owners of the building are usually persecuted so they pay damages to victims family.”* [Tweet row 150]. The regulator seemed to have been awakened by news of injuries and fatalities judging by this tweet from one of the leading regulators that read *“the council would begin to enforce the law as a measure towards ending the increasing rate of building collapse nationwide”* [Tweet row 4]. This gives the impression that the construction sector regulator needs to do more by way of being proactive. This finding is addressing question 2, which sort the perception of industry actors and users regarding OH & S performance in the Nigerian construction sector.



2. In-depth Interviews

In addressing question 1, the two participants in this scoping study were drawn from the construction and oil and gas industries, respectively. The former has a Building degree and works as a site manager for a local contractor with less than twenty employees. The latter has a Civil Engineering background and works as senior project engineer for a multinational. Their average year's of experience is fifteen. The themes that emerged from the interrogation of the transcripts were general OH & S cultures, organisational policy and procedures, organisational goal and objectives, utilisation of lagging and leading indicators, design/regulatory safety and regulatory practices and management.

In particular, there were divergent views regarding issues involving general safety culture and implementation of organisational policy and procedures in comparing the construction sector with the oil and gas industry.

When compared to the construction industry, there was evidence that the oil and gas sector appeared to be better regulated and has functional organisational policies and procedures. Subtle policy cascading was commonplace in the oil sector. For example, "it is standard practice to impress upon our vendors our own organisational culture and standards. This we achieve through training and meetings. No silo working allowed." [Participant 1]. The Department of Petroleum Resources (DPR) is the main regulatory body in Nigeria's oil and gas sector. DPR as an agency of the federal government seem to have capacity to monitor and regulate the activities of the oil sector. There is nothing in the data scrapped from Twitter to suggest that the perception was any different. The leadership commitment in the oil sector appear strong and with collective responsibility for OH & S. This was echoed by the one of the interviewee who said, *"In my organisation, everyone has responsibility for safety. I have the right to stop you from continuing work if I notice breach of company safety policy and procedure."* [Participant 1]

On the contrary, participant 2, though not an aggregate representation, participant 2, from the construction sector, suggested self-regulation was rife. With the perceived fault line being the existence of multiple regulatory agencies like the Council for the Regulation of Engineering (COREN) and the Council for the Regulation of Building in Nigeria (CORBON). Besides competing for influence and superiority, these regulatory bodies are both under resourced. They depend largely on annual membership subscriptions, which has adverse effect when it comes to proactive monitoring and regulating. For example, this interviewee said, *"On this 3 story building project, we are yet to receive visits from any of the regulators."* [Participant 2] Similarly, there is often trade-offs between cost, quality and safety. Most times, safety is compromised for cost and/or quality because profit margins are tight. Another example being, *"I am not suppose to be the one directly in charge of H&S but because of the nature of the work we are doing, and the company having debt issues I have been asked to... I have not been trained, and I have not being doing this work well because it is not suppose to be my job description, but I don't have a choice because if there is an accident on site it will still affect what we are doing."* [Participant 2] This is reflective of the findings of other commentators that there is too much focus on cost (Windapo and Jegede 2013), as well as the perception of data scrapped of social media that *"Government should be held responsible for building collapse in the country. contractors, builders and clients, always want to cut corners on their spending just to maximize profits, the endpoint is always what happened yesterday, I pray, may we never experience such again Ameen."* [Tweet row 166]. These findings suggest that the mechanism for the enforcement of the existing regulations is weak and unethical practices make self-regulation difficult. The outcome of the study highlights the need for the adoption of a more proactive approach (e.g., SLIs) to the management of safety in construction projects.



CONCLUSION

The results emerging from the study, which aims to estimate the rate of adoption of SLI as a tool for improving the practice of OH & S practices in the Nigerian construction sector, suggests that the perception of stakeholders on the practice of OH & S practices is one of trauma and hopelessness when accidents occur. Comparatively, there is a significant difference in the maturity levels of the safety management systems in the construction, and oil and gas sectors. The latter seems to be better resourced and regulated while the former is poorly resourced and have competing regulatory bodies fashioned along professionalism. Although there was no clear evidence of an understanding of what SLI is and how it can be exploited, the maturity level of the oil and gas sector was found to be at a satisfactory level, which is an indication of the industries preparedness to implement SLI approaches. The public perception of regulators of the construction industry is particularly poor and reactive. Overall, the findings strengthen the idea that the construction sector needs to adopt the use of proactive methods to improve the practice of OH & S. This goal can be achieved through the use of SLI as a guiding principle.

The study contributes to the understanding of safety management practices in the Nigerian construction sector. The main limitation of the current study is that the number of participants is small which makes it difficult to generalize the findings to a larger population. Whilst these findings are not generalizable, it shows that the construction sector utilizes a reactive approach to safety management. Also, the public perception of the construction industry is seemingly poor. Future studies need to conduct a large-scale investigation to validate the findings emerging from the current study.

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Causal Analysis of Crane Accidents Based on Human factors Analysis and Classification System

Linqi Zhou, Zhipeng Zhou

Nanjing University of Aeronautics and Astronautics, China

Correspondence: zhouzhipeng@nuaa.edu.cn

Abstract:

In order to systematically analyse human factors that lead to crane accidents, traditional Human factors Analysis and Classification System (HFACA) model has been modified to a four-layer Crane-related HFACS model to investigate human related crane accident causes. 141 crane accident investigation reports were collected during 2011 to 2020 in this study, and coded to identify human related causal factors according to Crane-Related HFACS. The coding result shows that Struck-by-load is the most significant crane accident type. The accident pathway network with the most frequent human-factor-chain shows that D12 Unsettled-safety-training, C12 Unsettled-hidden-danger, B11 Lack-of-safety awareness, A13 Staying-in-dangerous-area is the critical human-factor-chain that is most likely to cause Struck-by-load accidents. Therefore, particular attention should be paid to propose more targeted measures. The recommendations are provided based on this network to reduce crane accidents and improve engineering efficiency and quality.

Keywords: crane accidents; causal analysis; HFACS; human factors; struck by load.

INTRODUCTION

Lifting machinery appeared ten years B.C. as construction machinery. With the development of technology, a large number of different types of lifting equipment have emerged, which could liberate human labour from repeating reclaiming, moving, unloading and other actions. Its good ductility also makes it possible to greatly reduce the consumption of human resources and to improve work efficiency, therefore, lifting machinery has been widely used in construction, metallurgy, machinery manufacturing and other industries. However, in spite of substantially improving economic performance, the wide application of lifting equipment has also brought some problems. The constant occurrence of crane accidents affects the operation of projects, and even threatens the safety of operators, on-site personnel and nearby residents.

According to collected data, crane accidents have brought up more than 235 million RMB of economic damage and 255 deaths for the last 10 years, which have caused serious social influence. In order to reduce the occurrence of similar accidents, it is necessary to explore the causes of crane accidents to fundamentally solve the problem and promote the safe use of crane machineries.

In order to explore the causes of crane accidents, scholars around the world have used different methods to analyse crane accidents. American scholar Beavers, Moore et al. (Beavers et al. 2006) have proposed a crane accident classification system, according to the direct causes of crane accidents, they divided crane accidents into six types. Australian scholar Gharaie, Lingard et al. (Gharaie, Lingard and Cooke 2015) has systematically analysed the causes of crane accidents by classifying the collected accident data, and using Loughborough model to explore the direct causes, formation factors and root causes of the accidents, to get an accident pathway. Zhang, Zhang et al. (Zhang et al. 2020) divided the causes of crane accidents into six subsystems with 34 causes in total, pointed out the important factors of the accidents through sequence relationship research and decision-making test, and verified the reliability of the research by application of specific cases. Korean scholars Park, Kyo et al. (Park et al. 2007) applied man-machine system model to study the human factors of crane accidents from two

dimensions of information processing and lifting equipment life cycle.

Currently, most attention has been paid to the cause analysis and prevention of crane accidents around the world, however, there are only a small number researches have been carried out to specifically analyse human factors that cause crane accidents. It is necessary to analyse human factors in crane accidents in detail, as the installation, operation, maintenance and management of crane machinery are all closely related to human being. In this paper, 141 crane accident investigation reports was collected as raw materials, and Human Factors Analysis and Classification System (HFACS) model was introduced to do in-depth research on human factors involved in crane accidents.

MODEL

HFACS model was first proposed by Wiegmann and Shappell (Shappell et al. 2007) in 2007 to investigate human factors leading to accidents and analyse the potential causes of human errors. As is shown in Fig.1, it divided human factors into four layers.

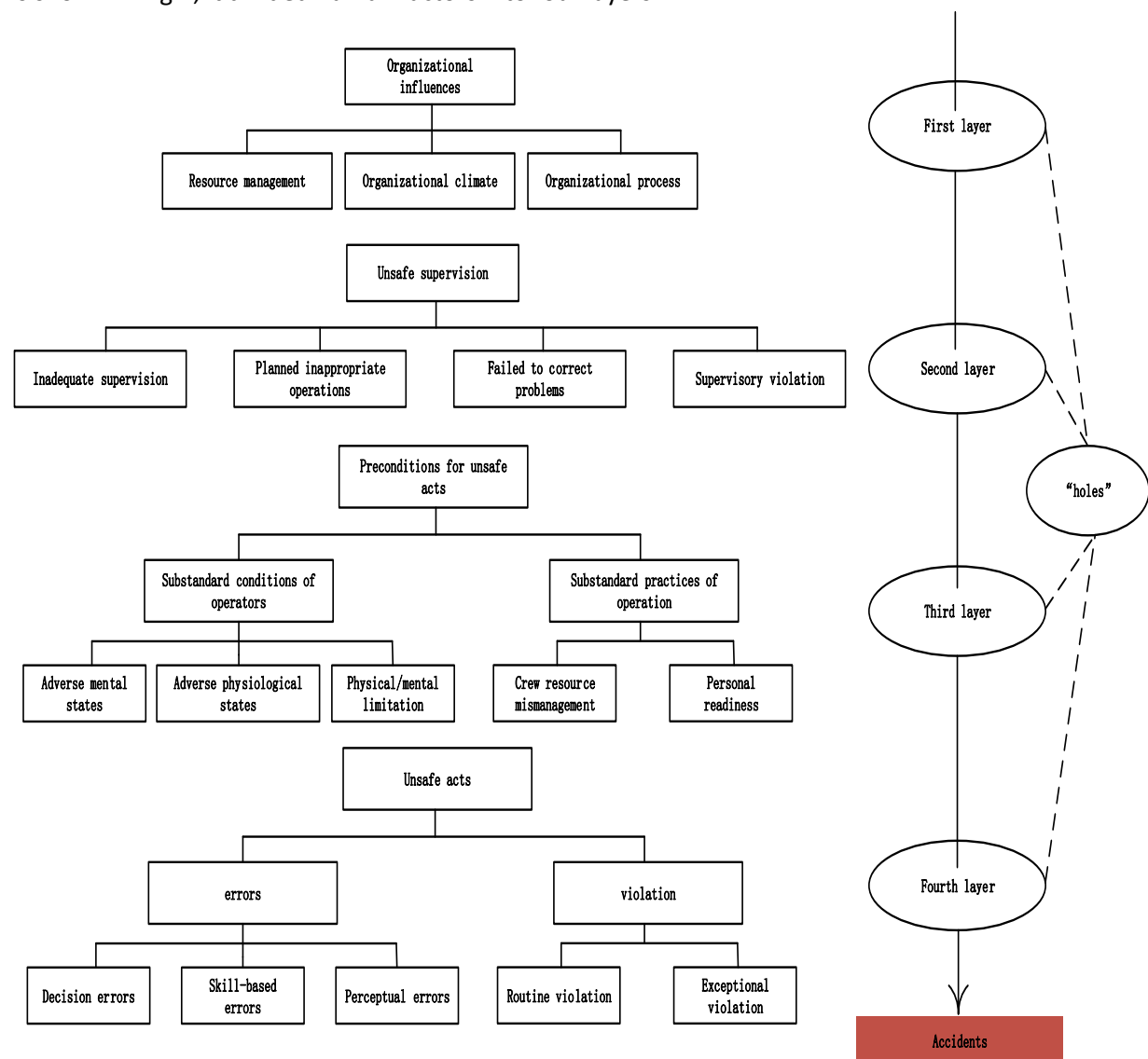


Fig.1. HFACS framework

Wiegmann and Shappell hold the idea that, similar to Reason model, human factors at all levels could be regarded as "holes" ,these "holes" in different levels might run through and connected as a line and thus leading to the occurrence of accidents, which means human factors of adjacent layers have certain degree of connection. To carry out the research in a more systematic way, apart from the distribution of human factors involved in accidents, the relationship of human factors between

adjacent layers should also be considered.

METHOD

Because HFACS model was initially designed to analyse aviation accidents. It cannot be directly used to analyse crane accidents. Therefore, the framework should be modified to be more suitable for this study.

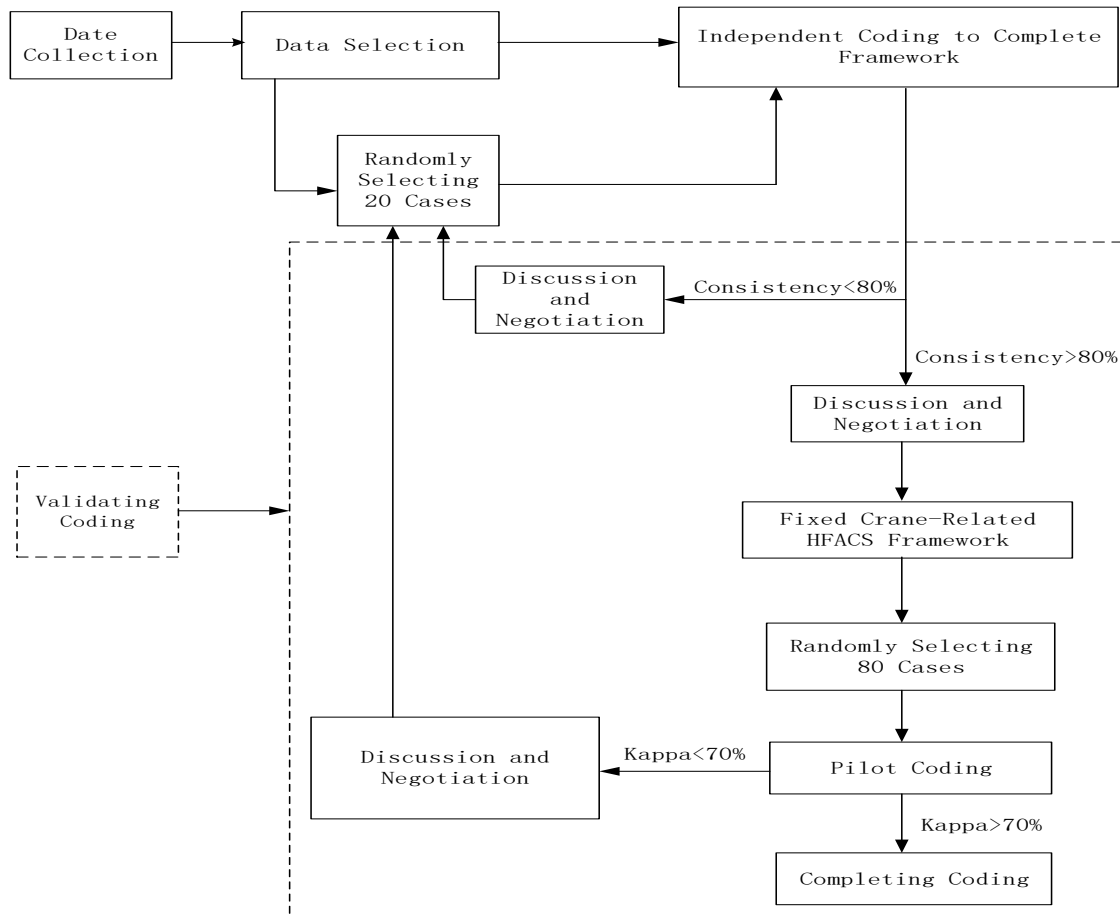


Fig.2. The process of the construction of Crane-related HFACS framework and coding

Fig.2 shows the process of the construction of Crane-related HFACS framework and human factor coding. First, crane accident reports for the last decade were searched online, and selected according to their integrity and correlation to this study. Based on the first two levels of original HFACS model and combined with 20 reports that were randomly chosen, two graduate students coded individually to complete the third level of the framework, according to the definition of original HFACS framework. Both of them have been engaged in construction accident safety research for six years. After coding, the consistency of two codes was calculated. If the consistency was less than 80%, after discussion of the problem, 20 accidents would be randomly selected again to complete the framework, if the consistency was above 80%, the framework would be fixed after discussion. After that, 80 reports were randomly selected to do independent pilot coding to figure out human factors that led to those accidents according to the fixed framework. After pilot coding, kappa value of both students was calculated. If the kappa value was less than 70%, after discussion and negotiation, the research would return to the step of selecting cases. If kappa value was above 70%, the stability and effectiveness of the framework would be proved, and then, accordingly, all accidents would be coded.

Crane-Related HFACS



Crane accident cases during the year of 2011 to 2020 were searched in a domestic commercial website. These cases were selected to get 141 complete crane accident reports. We imported the first two layers of HFACS framework and 20 cases to an Nvivo profile as coding nodes and raw materials respectively, the file was then sent separately to graduate students A and B to conduct independent coding. Definition of each coding node had been clarified before coding. The framework of Crane-related HFACS was eventually fixed as is shown in Table1.

Table 1: Crane-related HFACS framework

First Level	Second Level	Third Level	Detailed Description
A UNSAFE ACTS	A1 Violations	A11 Unauthorized-operation	Operating against rules and regulations
		A12 Command-against-rules	Willfully disregarding rules and regulations
		A13 Staying-in-dangerous area	On-site operators staying near the operating equipment
	A2 Errors	A21-Operator-error	Unintended operative error
B PRECONDITIONS FOR UNSAFE ACTS	B1 Substandard Conditions of Operators	B11-Lack-of-safety-awareness	Harmful state of mind, overconfidence etc.
		B12 Weakness-of-skill	Poor self-protection ability, low level of operation skills
	B2 Substandard Practices of Operators	B21 Inadequate-technical-preparation	Failure to confirm equipment reliability or specific technical procedures before operation
		B22 Lack-of-security-measures	Security precautions not provided or equipped by stuff
		B23 Understaffed	Lack of lifting drivers, lifting signalmen or other operators
		B24 Unqualified-operators	Workers lack the necessary skills or certificates
		B25 Poor-communication	Communication not carried out effectively within a team
	C1 Inadequate Supervision	C11 Unfulfilled-responsibility	Safety responsibility not fulfilled in place
		C12 Unsettled-hidden-danger	Ineffective investigation of hidden dangers
		C13 Formalistic-supervision	Ineffective daily on-site supervision
C UNSAFE SUPERVISION	C2 Planned Inappropriate Operations	C21 Unfixed-Responsibility	Unimplemented liability system, uncleared responsibility
		C22 Failed-technical-disclosure	Technical disclosure is not timely or thorough
		C23 Illegal-contracting	Including contract completely substituting administration
		C24 Illegal-organization	Organization of construction without complete procedures
	C3 Failed to Correct Problem	C31 Failed-correcting-concerns	Hidden danger not rectified in time
	C4 Supervisory Violations	C41 Censorship-not-strict.	Information and qualification not examined strictly
		C42 Absence-of-supervisors	Safety supervisors not actual performance on site
		C43 Improper-arrangement	Assigning work to unqualified staff

D ORGANIZATIONAL INFLUENCES	D1 Resource Management	D11 Understaffed-managers	Insufficient security administrators
		D12 Unsettled-safety-training	Safety education and training not implemented
		D13 Insufficient-safety-cost	Insufficient safety investment or improper use of safety funds
		D14 Equipment-management	Loopholes of management of equipment
	D2 Organizational Climate	D21 Leadership-defects	Failure to urge staff to fulfill liability
		D22 Organizational-mess	Organizational safety management in a mess
	D3 Organizational Process	D31 Unestablished-system	Unestablished safety responsibility system or department
		D32 Process-management	Lax contract management, unclear procedure

Polit coding

80 reports that had been randomly selected and Crane-Related HFACS framework were imported to Nvivo as coding materials and coding nodes respectively. The Nvivo file was sent to A and B to conduct polit coding. After polit coding, kappa value, which is an index to measure classification accuracy, was adopted to verify the effectiveness of the framework.

$$\text{Kappa} = \frac{Po - Pe}{1 - Pe}$$

$$Pe = \frac{a1 \times b1 + a2 \times b2 + \dots + ac \times bc}{n \times n}$$

- Po represents overall classification accuracy; ac represents number of real samples for each class; bc represents the number of samples of each class predicted; n represents total number of samples

After several round of negotiation, the kappa value was eventually above 70%, which could prove the stability of the modified framework, the rest of reports were coded accordingly together by A and B. The final coding result is shown in Table 2.

RESULTS

As is shown in Fig.3, the cases are categorized according to accident location. For the past decade, Liaoning province accounts for the most crane accidents (25 cases), followed by Guangdong (17cases), Shandong (16 cases), Hebei (13 cases), Jiangsu (12 cases) province. The crane accidents recorded in Jiangxi, Neimenggu, Shanxi, Xinjiang provinces are only one, respectively.

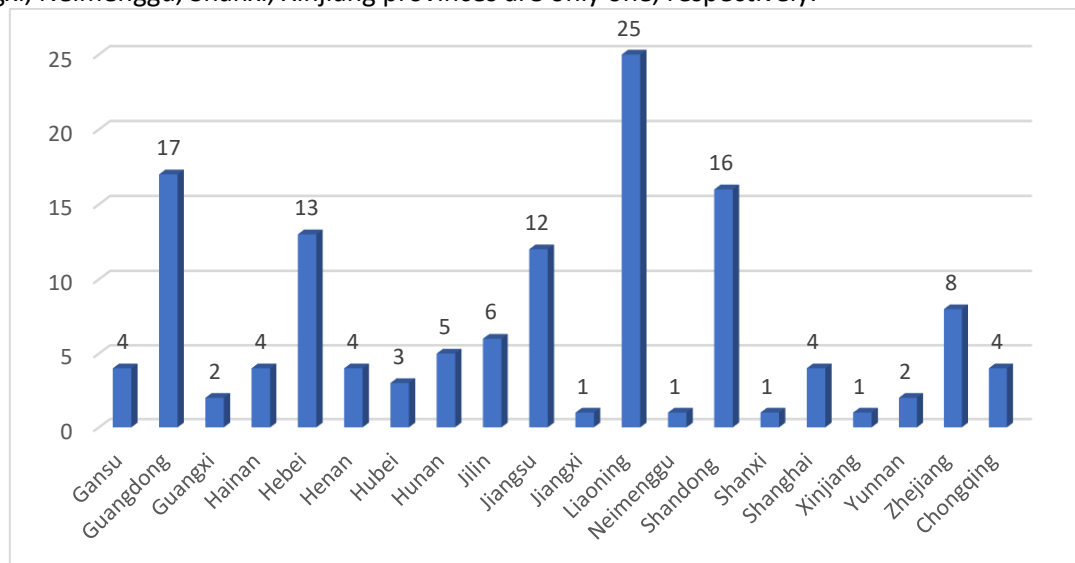


Fig.3. Distribution of provinces where accidents occurred

The overall coding result is shown in Table 2.

Table 2: Overall coding result

Coding nodes	Number	Coding nodes	Number	Coding nodes	Number
A11	100	B25	6	C42	10
A12	32	C11	58	C43	20
A13	40	C12	87	D11	52
A21	25	C13	95	D12	83
B11	82	C21	58	D13	6
B12	34	C22	31	D14	37
B21	57	C23	16	D21	50
B22	30	C24	16	D22	41
B23	20	C31	48	D31	41
B24	46	C41	27	D32	38

According to the classification system proposed by J. E. Beavers(Beavers et al. 2006), crane accidents could be divided into seven categories as is shown in Fig.4. The result shows that, Struck-by-load has the largest frequency of 42 (29.8%) among all 141 cases, accounting for the most part of all accidents, followed by Crushed (29 cases, 20.6%) and Destruction-of-metal-structures (22 cases, 15.6%). 20 cases (14.2%) are caused by Crane-instability, and 17 cases (12.1%) are caused by Falling-from-height. The Electrocuting incident does not occur in collected reports.

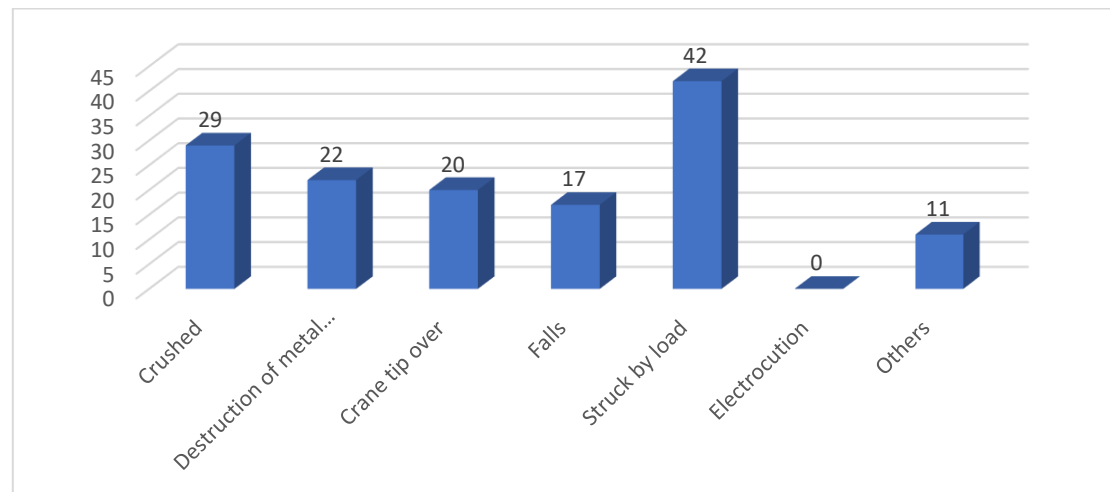


Fig.4. Distribution of crane accident types

Because Struck-by-load was the most typical type of crane accident, Crane-related HFACS framework was applied to do in-depth analyze of human factors of this accident type. The accident causal network that was proposed based on the statistical result of common cases of different factors of adjacent layers is shown in Fig.5. It indicates that D12 ---- C12 -----B11 ---- A13 is the most human-factor-chain that leads to the occurrence of Struck-by-load accidents.

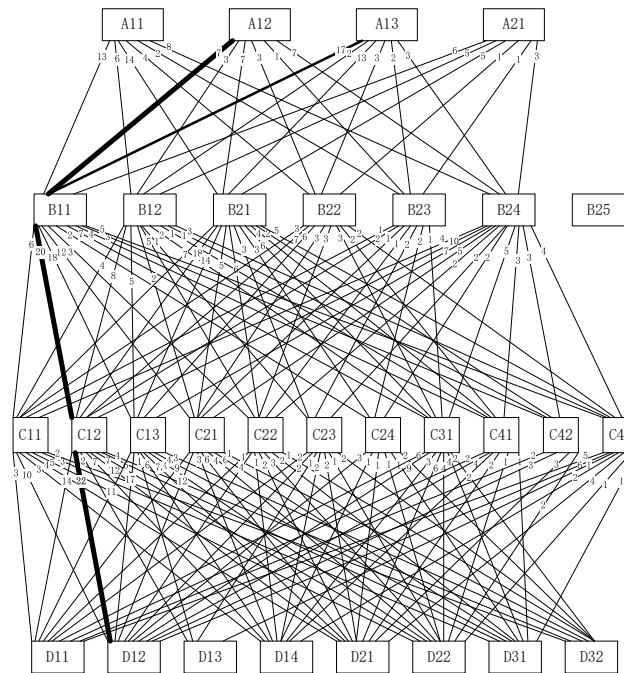


Fig.5. Accident causal network

DISCUSSION

Causal diagram and 5 Whys

Causal diagrams and 5 whys both are useful tools to do causal analysis as HFACS, but neither of them is more suitable than HFACS for the present study.

Causality diagrams are found to generate a directed acyclic graph (DAG) showing the causality between various factors based on background knowledge as the basement of followed statistical analysis, while the accident network of this paper was proposed based on the statistical analysis of a certain number of samples. Besides, DAGs do not provide information on the strength of visualized causal relationships, while the causality can be quantified in this paper to get the most frequent human-factor-chain.

5 whys technique means that "Why?" needs to be asked at least five times before the true root cause can be found. It is usually adopted to analyze a single incident to get a series of causal factors and corresponding solutions. In this paper, the researching objects is a certain type of accident, rather than a single incident. The suggestions are proposed to solve problems within the whole industry.

Crane-related HFACS

Final coding result indicates that, in the first layer, D12 Unsettled-safety-education-and-training was the most significant human factor. Crane, as a kind of special equipment, makes it important for frontline workers as well as managers of all levels to accept safety education and training. However, among 141 cases, more than half of these accidents involved inadequate safety education and training. Supervisors might lack necessary safety knowledge and ignore safety factors, as a result, risk monitoring measures were not taken appropriately or timely and frontline workers might lack enough safety awareness as well as professional skill competence that was supposed to be equipped before operating. Lacking training may also affect their ability to deal with emergencies. Another serious problem in the first layer was D11 Insufficient-security-management-personnel. During the operation of cranes, it is essential to arrange safety management personnel like on site supervisors and safety officers. Otherwise, the on-site environment would be in a mess due to lack of safety order maintainers.

In the second layer, C12 Unawareness-of-hidden-danger and C13 Formalistic-daily-supervision were the most frequent human factors. Although regulatory behaviors were carried out, they were mere formality and not effective at all. As a result, their stuffs were prone to get sluggish and treat their work with fluke. In addition, unawareness of hidden danger is likely to lay potential risk for on-site workers, and thus improving the possibility of the occurrence of dangerous situation.



In the third layer, B11 Weak-safety-awareness was the most frequent factor, followed by B21 Insufficient-technical-preparation-before-operation and B24 Unqualified-operators. In the fourth layer, the main human factor was A11 Operation-in-violation-of-rules, followed by A13 On-site-operators-working-or-staying-near-the-operating-equipment. After in-depth analysis, it has been found that weak safety awareness of crane operators might lead to the ignorance of regulations on operation manuals and thus leading to violation. For other on-site stuff, they were likely to enter working radius of equipment for letting down their vigilance. Insufficient technical preparation before operation might cause operators to operate merely based on their experience without specification. Lack of safety and reliability inspection added the possibility of occurrence of errors. Unqualified operators were often short of corresponding technology and safety knowledge, and were easily to cause violation or errors.

Accident types and causal network

Gharaie, E. (Gharaie et al. 2015) pointed out that the most prone type of crane accident was Struck-by-load accident, followed by Electrocution. In this paper, Struck-by-load is the most frequent crane accident, which is consistent with the previous study. The frequency of electrocution is zero, which has a lot to do with the effort made by researchers who worked hard on crane accident analysis, and the effort made by our government who controls the application of crane machines. Struck-by-load accidents were always caused by spreader damage or loosing binding. Such accidents are likely to cause serious economic losses as well as casualties and bring up serious social impact.

Causal network in Figure 5 indicates that, for Struck-by-load-accidents, D12 --- C12 --- B11 --- A13 was the most frequent human-factor-chain. D12 Lack-of-safety-education-and-training could affect supervisors both mentally and physically. It could cause the failure of risk monitoring, and thus influencing C12 Investigation-of-hidden-danger. Under these circumstances, it was hard for operation team members to clearly identify the risk factors in site environment. Most of victims of Struck-by-load-accidents were on-site workers. Due to weak safety awareness caused by inadequate safety training, on-site workers might be too casual to keep distance from operating cranes, which was found to easily cause crane accidents when combined with unsettled hidden danger as mentioned above.

CONCLUSIONS

To further study human factors in crane accidents, this study established a Crane-Related HFACS model, and obtained the following conclusions.

The Crane-Related HFACS model was modified from traditional HFACS model. Content analysis as well as independent coding and discussion were conducted to establish and validate Crane-Related HFACS framework which contains four layers and 30 human factors in total, and each layer contains three levels. It can be used to identify critical causes, more targeted measures can be taken to avoid crane accidents. Besides, it also provides a theoretical support for other scholars to carry out further researches in related area. The data was comprehensively collected and carefully selected, therefore, the statistical analysis results obtained here are relatively representative when considering overall safety situation of the application of cranes.

Coding result shows that Struck-by-load is the most frequent crane accident type, and A11 Unauthorized-operation, B11 Lack-of-safety-awareness, C13 Formalistic-supervision, D12 Unsettled-safety-training are the most high-frequency human causal factors of the four layers respectively.

A human factors network was built to quantitatively analyze the mutual causal relationships among different human factors from adjacent layers. It was found that D12 Unsettled-safety-training-----C12 Unsettled-hidden-danger-----B11 Lack of safety awareness-----A13 Staying-in-dangerous-area is the critical human-factor-chain that is most likely to cause Struck-by-load accidents, therefore, particular attention is supposed to be paid to propose more targeted measures.

According to the above conclusions, a few recommendations are provided to improve safety performance and develop more effective regulations. Firstly, strengthening safety education and training is supposed to be adopted to reduce accidents. Safety education and training should be held separately and specifically towards frontline worker and supervisors of all levels. Besides, certification mechanism is suggested to be established to ensure operators and supervisors have attended safety



training and are qualified enough for their working. Secondly, safety inspections of cranes and surrounding environment should be enhanced, including appointing responsible personnel, perfecting working records and logs. Thirdly, a database recording crane accidents including all relevant accidental features in the whole country should be established by related government department to facilitate relevant supervision and researches. Finally, numbers of sub-contractors should be severely restrained in order to avoid insufficient communication and lack of effective management.

There are still limitations in this research. Due to artificially coding, a certain degree of personal subjectivity is inevitable during this process. Besides, the collected accident reports are not enough to cover all crane accidents during the last decade. These limitations will be considered and solved in future researches.

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OBSERVED FACTORS CONTRIBUTING TO HUMAN ERROR ON CONSTRUCTION SITES

Lesiba George Mollo¹, Fidelis Emuze¹, and John Smallwood²

¹Central University of Technology, Free State, South Africa, ²Nelson Mandela University, Port Elizabeth, South Africa

Correspondence: lmollo@cut.ac.za

ABSTRACT

Accidents in the construction industry are connected to a chain of events that are caused by human errors. The purpose of this study was to assess factors causing human error on construction sites. The quantitative data were collected from multiple case study projects using non-participant observation protocols in Bloemfontein, South Africa. Gaps in communication, knowledge, safe work procedure (SWP), and skills were observed as error contributing factors in the study. The statistical data suggests that these factors are significant contributors to error manifestation. The results thus provide a reason to extend the study to better understand the dynamics of errors on site. The statistical data further outlines that the construction leaders do not mitigate the observed factors (including fatigue and distractions) contributing to human error. The identification of human error factors would help site management to reduce accidents on construction sites. Being error-wise is becoming a competence that site management must evolve in construction.

Keywords: Accidents, construction sites, human error, workers

INTRODUCTION

Construction is a highly physically demanding endeavour as activities are performed outdoor under conditions not conducive for the health, safety, and wellbeing (HSW) of people (Kamal et al., 2013). The impact of working in construction often results in accidents due to poor HSW implementation. For example, accidents are generally caused by the unsafe behaviour of the people and the unsafe state of objects, and the latter is ultimately caused by the human factor (Shi Wenwen et al., 2011). In particular, accidents in construction cost lives, create widespread environmental damage and generate a poor public image. According to Kamal et al. (2013), accidents in construction is experienced because of human factors such as worker's behaviour and safety culture among the workers. Dekker (2014) pointed out that the causes of accidents could be linked to human error.

The causes of human error could be traced to vindictive acts, confusion, misrepresentation, carelessness and absence of care, failures of consideration, and intentional infringements (Dekker, 2014). Thus, relevant data shows that more than 80% of the accidents are due to human error (Shi Wenwen et al., 2011). Kamal et al., (2013) highlighted that accidents are connected to a chain of events that are caused by human faults due to errors. To understand the causes of human error factors on construction sites. This study was aimed at assessing factors causing the human error on construction sites. The assessment of the identified human error factors helped the researcher to draw a conclusion with regards to how the human error factors were managed on sites. Therefore, it is critical to consider factors contributing to human error and to manage them accordingly to minimize accidents on construction sites.

LITERATURE REVIEW

According to Vondráčková et al., (2017), human error is defined as any unintentional or inadequate decision, taken at any level in the hierarchy of an organization, which is, or was inappropriate in a given situation. Furthermore, human error is defined as a systematically connected frame of individual work programmes involving the activities and operating environment (Grant et al., 2018). Human errors can occur in all human activities across an organization at a managerial, conceptual, or technical level in connection with mistakes in the construction project itself, mistakes made by the investor, mistakes made by those using the building, mistakes in supplier relations, mistakes in the maintenance of the structure, and others.

Thus, human error is categorized into a personal approach and a system approach (Reason, 2000). The personal approach is focused on the mistakes, errors, slips or lapses of individuals and blaming them for forgetfulness, inattention, and moral weakness. The system approach is focused on the conditions under which individuals work and tries and establishing measures to avert the errors and mitigate their effects (Reason, 2000). Furthermore, human error is measured as part of everyday operations and is defined as the result of wrong actions or decisions made by individuals at the wrong time and place in the workplace (Chiu & Hsieh, 2016).

Human error is an important factor affecting safety production in industries. Many studies have been conducted on the reduction of human errors in the industries (Reason, 2000; Hollnagel, 2005; HSE, 2009; Dekker, 2014). For example, it is discovered that factors contributing to human error are not limited to poor communication, knowledge and skills at work, site supervision procedure, availability of health and safety resources and teamwork procedure (HSE, 2003; HSE, 2009; Reason, 2008; Misiurek & Misiurek, 2017). Also, fatigue, workers distraction or attention failure, work stress and inability to identify hazards are reported as the factors contributing to human errors (Dekker 2014; Reason, 2008; Asanka & Ranasinghe, 2015). Therefore, Table 1 provides a summary and description of the factors contributing to human error, identified above, on a typical construction site. These nine identified human error factors are summarised and categorised by the researcher based on the review of the literature focusing on the reduction of human errors in the industries. Thus, each factor is summarised according to the author's descriptions.

Table 1: Factors contributing to human errors on construction sites.

No.	Factor	Description	Sources
1	Poor communication	This factor manifests through failure to transmit and understand required information for task completion between site management and the general workers.	HSE (2009: 11); HSE (2003: 15)
2	Fatigue	This factor manifests when working conditions lead to tiredness and inattention.	Dekker (2014: 97)
3	Knowledge and skills of the work related to a task	This factor manifests as limited competence to complete tasks effectively.	HSE (2009: 11); HSE (2003: 15); Reason (2008: 72)
4	Site supervision procedures	This factor manifests when managers fail to inspect, instruct, and coordinate the workers to ensure they work safely.	HSE (2009: 11); HSE (2003: 15)



5	Workers' distraction or attention failure	This factor manifests when the attention required to work is hindered.	Reason (2008: 42)
6	Availability of health and safety resources	This factor manifests when there is limited availability of protective equipment to undertake a task	HSE (2003: 15); Misiurek & Misiurek (2017: 225)
7	Work stress	This factor manifests as physical, emotional, or mental factors that often cause accidents.	Dekker (2014: 90)
8	Awareness to identify hazards	This factor manifests as the failure to recognize and identify hazardous working conditions.	Asanka & Ranasinghe (2015: 60)
9	Teamwork procedure	This factor manifests when people in construction fail to work together to realize task completion	HSE (2003: 15)

RESEARCH METHOD

This study was aimed at assessing factors causing the human error on construction sites. In total nine human error factors were identified as highlighted in Table 1. The assessment of these nine human error factors helped the researcher to understand the steps that site management are taking to manage workers behaviour that often leads to accidents. To realise this purpose, a quantitative research approach was adopted as recommended by Creswell & Clark (2018). The quantitative data were collected from multiple case study projects using non-participant observation protocols in Bloemfontein, South Africa. In total, there were three construction sites project that was selected by the researcher. The selection of the construction site projects was based on the nature of the projects, which was buildings works. This is because building work projects exposes workers to different hazards that have the potential to cause accidents if ignored or not prevented.

The non-participant observation was used to collect the data because it happens when cultural knowledge is acquired by observing the phenomenon from outside the research setting (DeWalt and DeWalt, 2011). Thus, in this study, the quantitative data was collected by the members of the construction team working on each case-study project. For example, the researcher designed the observation protocols using a structured close-ended questionnaire, as recommended by Creswell & Plano Clark (2018). Each of the observers (members of the construction team) was given a close-ended questionnaire survey, which was used to rate the human error factors and the questionnaire was designed using a scale of 1 to 5. In case-study Project 1, the researcher had an agreement with a safety manager (observer 1); in case-study Project 2, with a student supervisor (observer 2); and, in case-study Project 3, a safety officer (observer 3), to assist with the collection of the data. Based on the recommendation of Creswell & Plano Clark (2018), it can therefore be concluded that a purposive sampling approach was used to select the observer's because each observer was a full-time employee at a selected construction site project, and they were responsible to observe the workers behaviour with regards to the human error factors.

The design of the observation protocols was based on an in-depth analysis of the relevant literature as listed in Table 1. For example, observer 1, observer 2, and observer 3 were instructed to record the identified human error factors witnessed on each case-study project daily. The observation protocol was designed using a Likert scale, ranging from 1 to 5, where 1 represented (very poor), 2 (poor), 3 (good), 4 (very good), and 5 (excellent). In total, there were 60 observations collected from each case-study project (see Table 2). Each case study was observed for 60 days, and the observers were recording the close-ended questionnaires survey daily when workers were busy with their tasks. To avoid influencing the data, the observers were instructed not to inform the workers about being

observed for 60 days. The statistical package for social science (SPSS) was used to analyse the collected observation data to show frequency mean score (MS) and standard deviation and the results were used to rank the human error factors as shown in Table 3. Also, the reliability of the statistical data was tested using Cronbach's Alpha (see Table 4; Taber, 2018). The data from the multiple case-study projects were collected between July 2018 and April 2019 as part of a cross-sectional study as explained by Creswell and Clark (2018).

Table 2: Observation sample

Case project	Observer	Start date	Finish date	Total number of observations per day
Case-study Project 1: The new TFS distribution warehouse structure project	Safety manager	17 September 2018	1 December 2018	60
Case-study Project 2: The new University of Free State (UFS) South Campus Student Housing Unit 05	Student supervisor	1 October 2018	7 December 2018	60
Case-study Project 3: The new University of Free State (UFS) South Campus Student Housing Unit 06	Safety officer	14 January 2019	18 April 2019	60

RESEARCH FINDING

The observed factors causing human errors on construction sites.

This section contains the analysed statistical data rating of the identified factors contributing to human error on construction sites as illustrated in Table 3. The statistical data were collected from non-participant observations in multiple case-study projects in Bloemfontein, as outlined in Table 2 above. The analysed statistical data from the multiple case-study projects are similar. From all three case-study projects, the MS of all nine human error factors rated was below the midpoint of 3.00, which showed that all the human error factors identified were rated poor in the multiple case-study projects. The results further reveal that site management teams are struggling to mitigate the identified human error factors on their project sites since no factor was rated either good or excellent by the observers.

The human error factors which were rated close to the midpoint of 3.00, were found in case-study Project 1. For example, the availability of health and safety resources scored an MS of 2.98, work stress scored an MS of 2.90, and fatigue scored an MS of 2.80. Also, it was found that, in the case-study Projects 2 and 3, the human error factors identified were rated very poor and there was no single factor that approximated the midpoint of 3.00. For instance, the highest-rated factor in case-study Project 2 was the workers' destruction/attention failure with an MS of 2.63 and, in case-study Project, 3 it was work stress at an MS of 2.63. It was observed that the highest-rated factors in case-study Projects 2 and 3 were the same with an MS of 2.63. However, in all three case-study projects, the lowest-ranked factor was the awareness of the need to identify hazards. In case-study Project 1, the awareness to identify hazards was rated with an MS of 2.47; in case-study Project 2, it was rated with an MS of 2.46 and, in case-study Project 3, it was rated with an MS of 2.31.



Table 3: Factors contributing to human error on construction sites.

Factors	Case study Project 1		Case study Project 2		Case study Project 3	
	MS	Std Deviation	MS	Std Deviation	MS	Std Deviation
Open communication	2.63	0.920	2.54	0.771	2.52	1.062
Fatigue	2.80	0.860	2.60	0.736	2.59	1.102
Knowledge and skills of the work regarding a task.	2.60	0.828	2.56	0.823	2.43	1.015
Site supervision procedures	2.57	1.015	2.54	0.944	2.57	1.045
Worker's distraction or attention failure	2.70	0.830	2.63	0.937	2.60	0.997
Availability of health and safety resources	2.98	0.892	2.50	1.011	2.48	1.032
Work stress	2.90	0.878	2.52	0.899	2.63	0.911
Awareness to identify hazards	2.47	0.700	2.46	0.713	2.31	0.934
Teamwork procedure	2.52	0.911	2.58	0.942	2.55	1.090

Once the MS and standard deviation of the nine human error factors in multiple case-study projects had been calculated (Table 3), the reliability tests of the statistical data were calculated using Cronbach's Alpha as illustrated in Table 4. Therefore, it can be concluded that the statistical data presented in Table 4 was reliable. This is because the Cronbach's Alpha test in all three case-study projects was higher than 0.70 as shown in Table 4.

Table 4: Cronbach's Alpha for data from multiple case projects on human error factors

Case project	Cronbach's Alpha	Cronbach's Alpha Based on standardized items
Case-study Project 1: The new TFS distribution warehouse structure project	0.823	0.821
Case-study Project 2: The new University of Free State (UFS) South Campus Student Housing Unit 05	0.751	0.759
Case-study Project 3: The new University of Free State (UFS) South Campus Student Housing Unit 06	0.843	0.843



DISCUSSIONS

It is reported in the literature that accidents in construction are experienced because of human factors such as worker's behaviour and safety culture among the workers (Kamal et al. (2013). The impact of human factors in the industries is outlined by Dekker (2014). The author acknowledged that most of the reported accidents are linked to human error. Human errors can occur in all human activities across an organization at a managerial, conceptual, or technical level in connection with mistakes in the construction project itself, mistakes made by the investor, mistakes made by those using the building, mistakes in supplier relations, mistakes in the maintenance of the structure, and others (Vondráčková et al., 2017). According to Reason (2008), human error is described as the greatest contributor causing accidents in the industry.

This reported notion by Reason (2008; Dekker, 2014) that human error is the source of accidents in the industries is supported in the statistical results presented in Table 4. The results of this study show that from all three case study projects, the MS of all the nine human error factors rated below the midpoint of 3.00, which showed that all of the identified human error factors were rated poor in the multiple case study projects. These ratings suggest that the factors are significant or major contributors to human errors because they are rated poor instead of either good or excellent by the observers. For example, in case study project 1, it is discovered that awareness to identify hazards had the lowest MS of 2.47, while in case study project 2 it had an MS of 2.46 and in case study 3 it had an MS of 2.31. It can therefore be concluded that workers on construction sites struggle to identify hazards that could cause accidents. According to the report issued by Asanka & Ranasinghe (2015), a lack of awareness to identify hazards has the potential to cause accidents on construction sites. Therefore, it is critical to recognize and identify hazards before they could cause accidents that might affect the success of the project.

The results further show that the identified human error factors are rooted in the behaviour of people, which is portrayed as undesirable, unacceptable and showing a lack of attentiveness as recommended by Noroozi et al., (2013). It is evident in the research findings that indeed human error factors are rooted in the behavioural acts of the workers. The statistical data in Table 3 clearly shows that the human error factors are poorly rated. For instance, it is concerning or unacceptable that open communication by people working on construction sites, site supervision procedures and teamwork procedures are rated poor with a midpoint below 3.00 in the multiple case study projects. The identification of human error factors would help site management to reduce accidents on construction sites by improving worker behaviours. Therefore, it can be argued that indeed human error is measured as part of everyday operations on construction sites (Chi & Hsieh, 2016).

CONCLUSION

This study assessed factors causing human error on construction sites. The statistical data identified the human error factors which include, poor communication, fatigue, knowledge, and skills of the work related to a task, site supervision procedures, workers' distraction or attention failure, availability of health and safety resources, work stress, awareness to identify hazards, and teamwork procedure. These human error factors are consistent with the categorization of human error factors discovered in the research literature review. Furthermore, these human error factors are rooted in the behaviour of people working in the construction industry. The results thus provide a reason to extend the study to better understand the dynamics of errors on site. Therefore, it is recommended that more research should be undertaken to understand the essential drivers of human behaviour that cause human error factors in the construction industry.



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Work Ethic and Cognitive Models of Work: Contractors and Workers Perspectives on Elevated Injury and Fatality among Latino Workers in Small-Scale Residential Construction

Shannon Montgomery¹, Antonio Marin¹, Elsa Nunez Reyes¹, Thomas Mills², Michael Merten³, Hector Nolasco⁴, Joseph Grzywacz¹

¹Florida State University, USA, ²Virginia Polytechnic University, USA, ³University of Nebraska, USA, ⁴California State University, USA

Correspondence: jgrzywacz@fsu.edu

ABSTRACT

Purpose. Small-scale residential construction contractors are of great interest to the field of construction safety because young Latino workers in this subsector have among the highest rates of injury and fatality. This study sought to determine how contractors and workers employed by small contractors think about the nature of their work and their work ethic. **Design.** Qualitative semi-structured interviews were undertaken with n=4 Latino contractors and n=8 Latino workers in the framing and roofing trades of small-scale residential construction. Interviews were recorded, transcribed verbatim, and analyzed for dominant themes and patterns. **Findings.** Contractors and workers held a comparable work ethic. Contractors' and workers' status in the U.S. as an "immigrant" shaped how they thought about the nature of their work and contributed greatly to their work ethic. Because of their immigrant status, both contractors and workers believed they had to "work harder" and "faster" than their American counterparts to demonstrate their value. However, "working hard" and "fast" impeded safety. Workers were often willing to forgo safety precautions and discounted injury risk believing it is at odds with making money needed to support themselves here and family in Mexico. Additionally, traditional Latino cultural norms shaped their belief systems about safety risks, for example, through superstitious beliefs and a "stubborn" nature. **Limitations.** The generalizability of study findings is unknown because the data are from a small, regional sample of contractors and workers in two trades of small-residential construction. **Implications.** Safety interventions in framing and roofing trades of small-scale residential construction must acknowledge the immediate survival demand (i.e., the need to support two families) that underlies worker behavior in the industry. The possibility of potential injury is an important, but comparatively distal threat relative to the short-term financial loss.

Keywords: small-scale residential construction, immigrant Latino workers, worker safety, injury inequalities

INTRODUCTION

In 2015, Latino immigrants accounted for 28.6% of the United States (U.S.) construction workforce, an increase from 9% in the 1990s (White and Neely, 2004). Recent research showed that Latino immigrants were nearly 30% more likely to suffer work-related injuries than non-Latino white American workers (Dong, Men and Ringen, 2010). According to occupational health disparities research, characteristics such as age, being an immigrant, a racial minority or a temporary worker, can increase the risk for occupational injuries (CDC, 2011). Subsequently, a recent report highlighted the need to focus collectively on the complex system of multiple risk factors contributing to disproportionately greater prevalence of accidents in young, immigrant Latino construction workers, rather than focusing on the individual risk factors (National Institute for Occupational Safety and Health and American Society for Safety Engineers [NIOSH & ASSE], 2015).



Young, immigrant Latino construction workers often belong to multiple vulnerable populations, which increases their risk for work-related injuries on the construction site (NIOSH & ASSE, 2015). In 2013, Latino construction workers were the only racial/ethnic group with an increase in the number of U.S. workplace fatalities (Byler, 2013). Several key factors contributing to the increased risk of injury include language, cultural and structural barriers, communication issues and lack of supervision (Al-Bayati and Abudayyeh, 2016). One of the most prevalent risk factors is lack of safety, whether due to lack of safety training or lack of adherence to safety protocols (Hung *et al.*, 2013). Previous research has indicated that immigrant Latino construction workers are reluctant to adopt safety procedures or undergo safety training as they believe it is of limited value (Hung *et al.*, 2013; Arcury *et al.*, 2014). However, a recent qualitative exploration found that Spanish-speaking immigrant construction workers attributed their safety experiences to employers' unwillingness to enforce safety regulations and employer discrimination due to legal status or lack of documentation (Díaz Fuentes *et al.*, 2016).

Previous research indicates that small scale employers and contractors are less likely to enforce safety regulations amongst their workers compared to larger construction companies (Díaz Fuentes *et al.*, 2016). Such evidence suggests that there is a complex system of influencing factors that contribute to the lack of safety measures adopted on the construction site. However, the literature that guides our understanding of targeting safety behavior change is under-developed. Research has called for programs to be evaluated to improve safety behaviors (Arcury *et al.*, 2014) and for training programs to be culturally tailored to the specific population (Dong, Men and Ringen, 2010). Recent evidence has outlined the need for further investigation into the role of both structural (i.e. regulations) and individual factors (i.e. literacy) affecting attitudes towards the trade-off between job security and occupational safety (Díaz Fuentes *et al.*, 2016). Collectively, such evidence suggests there is a need to investigate the construction workers' perspectives on safety measures, to appreciate the interacting influences motivating their safety decisions.

Theoretically, previous cognitive models on health self-management can be applied to the competing influences contributing to Latino workers' injury risk on the construction site. The interaction between health, illness and healthcare-related aspects of society has been previously described as a cultural system (Kleinman, 1978) linking beliefs, experiences, behavior, decisions, practices and evaluations. The cultural system as it relates to health can provide guidance for how we might better understand cognitive models underlying safety-related decisions (or lack thereof). Additionally, the Common-Sense Model of Self-Regulation (CSM) is a conceptual framework that provides understanding of the perceptual, behavioral and cognitive processes involved in health self-management (Leventhal, Phillips and Burns, 2016). Concepts in the CSM are multi-level, representing the mechanisms and processes underlying self-management of health-related threats, previous histories, and strategies for action and maintenance (Leventhal, Phillips and Burns, 2016). Collectively, such models are useful in thinking about the different factors contributing to Latino workers' cognitive processes about safety and may provide insight into how they think about their work ethic that incorporates safety. Therefore, this study aims to investigate how immigrant Latino construction workers' work ethic impacts how they think about their safety

METHODS

Study design

This research is part of *iPonte Listo!*, a sequential mixed-methods study of occupational safety among immigrant Latino workers in the small-scale segment of the residential construction industry in Tulsa county, OK. The data for this analysis are from the qualitative component of the project including the Latino construction workers and contractors.



Participant recruitment

Recruitment was facilitated by the research teams' previously established relationships with organizations serving the immigrant Latino community. The inclusion criterion for "contractors" in this study was: (1) owner of a construction establishment with fewer than 9 workers for at least 3 years, (2) majority of revenues were from activity in residential construction, and (3) having had one or more immigrant Latino workers for a minimum continuous period of 6 months. The inclusion criterion for "construction workers" in this study was: (1) self-identify as Latino, (2) employed in the residential construction industry for at least 1 year, and (3) worked as a framer or roofer in residential construction for 20 hours or more in the past month. Family members, who were first-degree relatives of an immigrant Latino construction worker were also interviewed, but they have not been included as part of this study. Study participants were recruited by trained bi-lingual study staff.

Data collection

Study procedures were approved by an Institutional Review Board. Data were collected by two trained interviewers from December 2019 through February 2021. Interviews were conducted at locations of the participants' choosing, usually their homes. Prior to any data collection, participants were informed of the purpose of the research and reminded that participation was voluntary. Signed informed consent was obtained from all study participants. Data collection did span the COVID-19 pandemic, resulting in n=22 interviews that were conducted in an in-person, face-to-face environment, and the remainder (n=17) conducted through Zoom. Participants received a \$25 incentive at the end of the interview. Digitally recorded interviews ranged in length from approximately one to three hours.

Interview Content

The goal of the qualitative component was to gain understanding of the knowledge and beliefs surrounding occupational safety and injury held by the workers themselves and their "employer", the contractors. It is important to acknowledge that the workers and contractors often consider their 'boss' to be a figure of authority, or whoever pays them. Therefore, the 'boss' is context specific, dependent on their role. In some cases, the 'boss' is the individual who contracted the work to the contractor. The interview guides for each of these stakeholder groups was distinct, but they shared a common set of content. All interviews began with basic information about the participant. Then the interview moved into questions to probe basic beliefs about hazards confronted by workers in small-scale residential construction, and the perceived causes of common injuries experienced by construction workers including falls from heights, strains, and injuries from equipment.

Analysis

All interviews were digitally recorded. The first 26 interviews (4 contractor, 8 worker, and 14 family members) were transcribed verbatim in Spanish, and then translated into English by a professional transcription service. All investigators reviewed each of these transcripts and determined that theoretical saturation had been reached. However, given the small number of interviews in some segments of the sample (i.e. n=4 contractor interviews), the research team decided to continue interviewing to verify that data saturation had been met. Two bilingual team members reviewed each interview independently to determine if any "new" information was gained and individual case-studies were created. It was confirmed that no new information had been gained. Therefore, the interviews (n=13) were not translated and transcribed. All the translated transcripts were uploaded into NVivo 12 (Version 12 QSR International Pty Ltd. NVivo qualitative data analysis software, 2018) for data management, coding, and to facilitate analysis. A coding dictionary was constructed based on a-priori content underlying the construction of the interview guide (e.g., controllability of injury, beliefs about safety) as well as new ideas that emerged from immersion into the data. Two team members independently coded each transcript. The vast majority of codes had excellent inter-rater



reliability (Cohen's Kappa ranged from 0.8-1.0). Some of the codes had poorer inter-rater reliability, but coding agreement was achieved through discussion.

RESULTS

Participant characteristics

This study included n=8 Latino construction workers and n=4 contractors from framing and roofing trades. This study included n=8 Latino construction workers and n=4 contractors from the framing and roofing trades of. All participants were male, and most participants did not graduate from High School. The contractors ranged in age from 29-34 years and had spent on average 15 years in the U.S. The workers ranged in age from 18-50 years and had spent on average 12 years in the U.S. Full descriptive information for the sample is included in Table 1.

This study elicited two major themes, reflecting the intersection of the association between culture and work ethic. Themes and associated sub-themes are outlined below.

Theme 1. The work ethic of immigrant Latino construction workers is strongly related to their general immigrant status within the U.S.

Many immigrant Latino construction workers in the U.S. are undocumented and construction is one of the few sectors where undocumented immigrants can "make a good living." Therefore, the belief that immigrant Latino construction workers have a work ethic to work fast, with minimal attention to safety risks, is partially a consequence of the vulnerability of their legal status as an immigrant worker in the U.S. This is particularly pertinent given their lack of employment opportunities, and competitiveness from other undocumented workers who would gladly replace them. Participants formed belief systems based on their immigrant status, conveying immigrant-context-specific implications. These indicated that the cultural norms surrounding their work ethic were not solely related to Latino culture, but rather, as a consequence of being an immigrant worker within the U.S. Four sub-themes are discussed below:

Sub-theme A: Immigrant work ethic centers around working hard and fast because working hard and fast is the best policy when you're undocumented

Immigrant Latino contractors and workers collectively portrayed that their work ethic emerged due to their circumstances. In particular, the need to work hard and produce results stemmed from internalized pressure to remain employed. For immigrant contractors and workers, losing their job could result in unfavorable consequences, as they would have few alternative employment options within the U.S., due to their (often undocumented) immigrant status, unlike their American counterparts:

"They [Americans] go to work and take precautions. On the other hand, we only want to push somebody out, so that we can take his place. We always say that Americans don't do anything, but we're wrong. They do things at their own pace, while we rush around killing ourselves to get it done. Latinos don't work slowly. We rush and run." Worker (W)3

The participants suggested that work ethic is not a result of being Latino, but rather, being an immigrant worker in the U.S. For many immigrant workers, they came to the U.S. to work, make money, and provide for their family. Therefore, they are under pressure to work hard and keep their job. This often resulted in working fast, to reduce the risk of being replaced by another worker, contributing to safety risk:

"it would be a little bit difficult to make us change the way we think because it's something deep-rooted with us. It's something cultural about us. We come to this country to work and make money. That's what is in our minds. And since most of the people working in construction make money according to what they do during the day, they work very quickly to finish the job as soon as possible. I think, because of that, workers may neglect safety. They're always rushing." Contractor (C)1



Sub-theme B: Immigrant Latino workers minimized the risks to safety and were more accepting of the potential hazards involved

Participants reflected the thoughts of many within the industry, because whilst there are known risks to safety, the majority of workers do not consider the risks to be of immediate threat to them personally:

"Most of us have a mindset that nothing is going to happen. I'll just get up there, and nothing will happen, or we think, it's not the first time we've done that. Or we say, 'I know how to do that.' For that reason, we don't use the appropriate equipment." C1

However, whilst they understood that some level of risk is involved in their work, participants discounted the risks in favor of the benefit. In the moment, the benefit of working faster and making more money, out-weighed working slower, or spending time adopting safety behaviors, despite the risk to safety:

"We don't take precautions because we think only about money and don't measure the consequences." W5

"You could train a person, but I think it's very difficult to try to think the way people think. Our mindset is if we work less, we're going to make less. And the equipment is going to hinder us from doing our jobs. For that reason, we don't use it." C1

Furthermore, they considered prior experience to be more protective of risks compared to adopting safety precautions:

"If you tell them to wear a harness, they ask you, 'Why? I don't need it. Nothing is going to happen. I've done the same thing 1000 times.'" C6

Sub-theme C: Working fast and working safely were competing motivations for Immigrant Latino workers

Immigrant Latino workers conveyed financial pressure to make money. In particular, this pressure came from the need to provide for 'two' families, one in the U.S. and one back home:

"In this country, we have responsibilities, not only those of our own. As much as I have responsibilities here, I have responsibilities in my own country, and I have to meet them." W1

In working fast, they were able to make more money, as they were paid by the job. Not only do workers feel pressured to work fast, but contractors also felt pressure to finish the job quickly so that they would continue to be offered jobs by employers or 'bosses'. They eluded to having to maintain the same productivity as when they first arrived in the U.S., and were recognized for working quickly: *"The bosses realized that Mexicans were able to do a good job and do it quicker than anybody else. So, they started to hire us... we were working three of four times harder than the people who had been doing the job. The bosses realized we were more productive and made them more money. So, they started giving us the contracts. Then, it became well-known that we were very good workers. So, now, we want to keep that fame and don't want anybody to out-do us. That creates a problem. Although productivity is high, it interferes with safety. Safety slows you down. We don't want to waste time being safe and have productivity go down." C6*

In many circumstances working fast goes against working safe, because implementing safe working practices takes time (and that time could be spent working):

"Since I'm not going to pay them extra for wearing the protective equipment, they will pay me so they don't have to use it. Really, they say they will pay not to use it, especially the harness because it's very uncomfortable. You don't work the same with the harness on and you lose too much time. Without the harnesses, we can finish a job in two hours. Wearing it, it would take about four or five hours. That's too much time wasted." C1

Sub-theme D: Immigrant Latino workers are less 'protected' due to their legal status compared to other U.S. workers in a similar industry



Participants spoke about their lack of documentation and legal status, which was associated with riskier behavioral choices and contributed to their desire to maximize their monetary gain:

"When we come to this country without documents, we take risks and do whatever is available to us. We want a job and to make good money." C2

Beliefs like those just described contributed to a feeling that workers needed to prove their worth and ability, as they were competing for jobs with construction workers with legal documentation. They were willing to take additional risks to ensure that they continued to be offered work:

"We don't want the [boss] to come and see us standing there. We want the [boss] to fire the person standing around. I think it's because of envy. We think the American is doing less work and getting paid better. So, we want him out of the way. I think that since we invaded this country, we don't have the right to complain –maybe, we do have rights, but which ones? We come here by running through hills and deserts to get here to work. We're illegals. So, we don't have to compare ourselves to an American." W1

Furthermore, participants eluded to the consequences associated with speaking up if they didn't feel safe or required protection:

"When I injured my fingers and was taken to the hospital [the doctor gave] me a week's medical leave... And, then, she extended the medical leave from one week to one month. But, then, I had another problem.. I went to see the doctor and asked her to release me because I wasn't making enough money. She called the company and made them pay me my 40 hours, plus back-pay. Well, the manager was mad at me. And, anytime I went to pick up my check, he [the manager] threw it at me. He acted like I had done something to him. But I did what I was told to do by the doctor." W4

Theme 2: Latino-specific cultural beliefs influenced workers' work ethic

Whilst participants portrayed a work ethic that was strongly related to being an immigrant in the U.S., they eluded to specific beliefs related to Latino culture that helped shape their work ethic. Belief systems that were evidently related to Latino workers as an ethnic group allowed for insight into how specifically Latino norms influence work ethic.

Sub-theme A: Latino cultural norms shaped their belief systems about safety risks

Traditional Latino cultural norms impacted on participants' belief systems, which shaped their work ethic. For example, some workers were superstitious about talking about the risks of construction work. It was their belief that talking about potential risks could put a curse on them. As a result, this contributed to workers avoiding talking about the potential risks with one-another:

"If you tell them about the possibility of having an accident, they don't like it. They think you're putting a curse on them. if you start telling them they could have an accident, they get mad and say you're wishing them bad luck. It's a little bit of...superstition" C6

In addition, they conveyed that many workers have a stubborn nature, that is part of their culture. As a result, this contributed to unwillingness to listen to safety information:

"Another problem is that Latinos are very stubborn and want to do things their own way. We want to do things the way we think is right... They take unnecessary risks while they do the job. That's a situation where you have to battle with them. You tell them not to take those risks and to do things the right way, even if it takes longer. But they don't listen." C6

Participants highlighted that Latino workers often have a relaxed attitude towards safety behaviors. Therefore, whilst they are aware that they should implement safety behaviors, the social norm is that it is not necessary to do so:

"The patron's responsibility is to tell you to wear the protective equipment. It's up to you whether you do it or not. We're free. The patron can't force you to do it. We're free to do whatever we want... It's up to you to listen or not" W5

Participants believed that workers were responsible for their own safety. This can be attributed to their prior beliefs of safety. For example, they are less likely to be familiar with employee protections in their home country and therefore do not assume that their bosses have a sense of responsibility:



"If I fall and get injured, somebody else is going to do my job... the responsibility is mine because I have to take care of myself... I, as a worker, have that responsibility. If it were the patron's responsibility, and I had an accident, they'd pay me for that. So, it's not the patron's responsibility. We, as workers, have to take precautions to prevent accidents." W3

DISCUSSION

Construction contractors' and workers' immigrant status within the context-specific setting of the U.S. shaped how they thought about the nature of their work and contributed greatly to their work ethic. Participants discussed their motivations to often overlook safety procedures, which emerged from pressures associated with their situational circumstances. Many immigrants are undocumented and are sometimes illegal workers, therefore they have an underlying self-initiated pressure to work efficiently or risk losing their job. Because of their legal status and education level, losing their job would result in few occupational opportunities, especially in the midst of a national pandemic and anti-immigrant administration. Furthermore, immigrant Latino workers are often financially providing for "two" households, themselves and their own family in the U.S. and their family back in their hometown of origin. Therefore, it should be acknowledged that immigrant Latino workers' drive to work efficiently, be productive and work fast may be a consequence of their situational circumstances. As a result, they are often willing to overlook safety precautions because the benefit of making more money in the short-term outweighs the potential risk of injury.

Whilst the findings in this study are specific to immigrant Latino construction workers in the U.S., parallels can be drawn with other immigrant groups in other locations. A study including undocumented immigrants from Mexico, Central and South America, and the Middle East, found that work ethic was characterized by motivation to make family proud (Autin *et al.*, 2018). Furthermore, a recent systematic review found that immigrants in Europe and Canada were more likely to be employed in jobs that were part-time, with a lower level of autonomy and fewer opportunities for development, despite being over-qualified (Sterud *et al.*, 2018). Such evidence suggests that regardless of the contextual setting, immigrants may be at greater risk of accident or injury because they are faced with a challenging prospect between keeping themselves safe, thereby requiring them to spend time and effort taking safety precautions, with the possibility of losing out on money and risk losing their job, as they are in competition with other workers, and could be easily replaced if they do not prove themselves to be hard workers.

These findings suggest that there are conflicting influences that contribute to lack of safety behaviors adopted on the worksite, contributing to higher rates of injuries in Latino construction workers compared to their American counterparts (Dong, Men and Ringen, 2010). Their situational circumstances encourage them to work faster to make more money. In doing so, they limit their focus on the potential risks. Delay discounting occurs when an individual chooses an immediate, smaller reward, over a larger potential reward over a longer period of time (Rachlin and Green, 1972; Koffarnus and Bickel, 2014). This can be observed in negative behaviors that, although may be potentially rewarding in the short-term, are often detrimental in the long term (Amlung *et al.*, 2017; Bickel *et al.*, 2019). Often, the short-term gain of making more money in a single day, is more rewarding in the participants' immediate future, compared to the possibility of an accident happening at some unknown point. Due to their situational circumstances, workers are willing to discount the risk of accident or injury, as they are focused on working fast to gain financial reward and provide for their family. In addition, the findings suggest that Latino workers are aware that they are taking some risks to their safety, however, Latino cultural norms influence them to be less likely to adopt safer practices. Specifically, workers identified a relaxed attitude towards risk potential, 'it won't happen to me'. In addition, Latino 'stubbornness' was identified. Although they are aware that negating safety precautions carries risk, the competing pressures to work fast, alongside with the social norm that



safety equipment was a choice, not a requirement, contributed to poor adherence of safety precautions.

Implications for research

The findings from this study suggest that the cognitive models underlying beliefs about work ethic are constructed from two distinct cultural contexts. The first is the context-specific norm of being an undocumented immigrant in the U.S. and corresponding challenge of competing for work and retaining employment. The second is the cultural norms related to ethnic groups that exert influence on cognitive models of work ethic. For example, the participants discussed specific Latino cultural norms, such as superstition, clouding their desire to talk about risk of accident or injury. The intersection of such cultural norms has important implications for interventionists attempting to deliver safety behavior change training. A previous review highlighted that many programs targeting immigrant, and specifically Latino workers in high-risk industry settings, do not embrace cultural models (Menger *et al.*, 2016). In line with this, these findings highlight the importance of acknowledging the ethnic group who is being targeted and tailoring the training accordingly. However, this study is limited by the generalizability of study findings, which are unknown because the data are from a small, regional sample of contractors and workers in two trades of small-residential construction.

CONCLUSION

The findings from this study suggest that the intersection of two forms of culture; context-specific culture shared by all immigrants to the U.S., and those distinct to traditional Latino culture contribute to the work ethic and resulting safety behaviors (or lack thereof) of immigrant Latino construction workers. When attempting to deliver safety training, health and safety practitioners should be attentive to the ethnic culture, but also acknowledge the struggles of survival of any ethnic group within the sociocultural norms of the setting. Importantly, this highlights that immigrant workers' work ethic stems from the need to prove themselves to survive in a competitive work environment, or face being replaced.

CONFLICT OF INTEREST

The authors declare there are no conflicts of interest.

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Table 4: Participant demographic information

# Interview	Age	Years in the US	Gender	Marital Status	Years of Education	Years in Construction
Contractors						
1	34	14	M	Married	High School	10
2	29	10	M	Married	11th grade	9
4	31	19	M	Married	5th grade	11
6	NA	17	M	Married	NA	17
Workers						



1	37	19	M	Divorced	Middle school	18
2	18	2	M	Single	NA	1
3	50	23	M	Married	3rd grade	15
4	38	19	M	Married	8th grade	14
5	25	5	M	Single	Universidad	5
6	20	4	M	Single	9th grade	4
7	31	15	M	Married	High School	15
8	37	9	M	Separated	5th grade	4

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APPLICATION OF THE WORKER ENGAGEMENT MATURITY MODEL TO AN INDUSTRIAL SERVICE ORGANISATION

Dick Robinson, Billy Hare, Kenneth Lawani, Iain Cameron

Glasgow Caledonian University, Glasgow, UK

Correspondence : B.Hare@gcu.ac.uk

ABSTRACT

The aim of the research described in this paper is to validate an existing Worker Engagement Maturity Model (WEMM) that was designed to evaluate WE in health and safety (H&S) in the construction industry and also determine if the WEMM could be applied to evaluate WE in the Industrial Services (IS) sector. This qualitative research used a literature review to validate the five psychological constructs (Meaningful Discussion, Motivation, Trust, Commitment and Empowerment) from an existing WEMM. Further validation was obtained via an expert panel. The methods employed 12 semi-structured interviews with workers at three locations. Thematic coding analysis was undertaken to fully understand workers' perceptions of engagement in H&S. The research found that the WEMM is a valid and reliable tool for evaluating WE in H&S in the Industrial Services sector. An amended WEMM was developed and this would benefit from further testing in other public and private sector organisations. The study was bound by the limitations of time and resources of a Professional Doctorate, which limited the sample size. This study has contributed to the existing body of knowledge on Worker Engagement in H&S by validating an existing evaluation tool in another industrial sector. The research has also further developed the maturity levels designed to evaluate WE in H&S.

Keywords: meaningful discussion; motivation; trust; commitment; empowerment.

INTRODUCTION

Townsend (2013) indicates that the level of reduction in global workplace accidents (including in the UK) has gradually declined over the past three decades. Townsend suggests that this is a phenomenon affecting developed industrial nations worldwide. Despite a tendency for organisations in developed countries to aim for 'zero harm' Sherratt and Dainty (2017) describe a 'zero paradox', where organisations espousing zero accident mantras appear to slightly increase the likelihood of employees sustaining major injuries or even fatalities. Such strategies invariably employ a Behavioural Safety Programme (BSP), focused on behavioural modification techniques (Hopkins, 2006). However, BSPs require administratively complex information capture, monitoring and reporting systems that gather data about frequent, easy-to-observe behaviours. This activity does little to prevent catastrophic industrial accidents (Sherratt and Dainty, 2017).

In order to improve H&S performance in the 21st century, it is proposed that change is required to the current intensive and overly bureaucratic model for H&S management. The views, opinions and ideas for improvement originating from workers (i.e. those closest to the risk) need to be taken into account. Since the 1990s, the term 'Worker Engagement' (WE) in relation to H&S has been increasingly recognised and researched (Schaufeli, 2012). Research by Hare et al. (2017) on a Worker Engagement Maturity Model (WEMM) has identified the increased importance of mechanisms to evaluate the extent of worker engagement in H&S within construction site workforces. Factors identified by Hare et al. as influencing the extent of WE were trust, commitment motivation, empowerment, and meaningful discussion. This model was developed primarily for construction, however, there is



potential to apply it in other sectors such as industrial services, where similar working environments and contracting arrangements exist. The aim of the research described in this paper is to validate the Hare et al. WEMM and determine if it could be applied to evaluate WE in the Industrial Services (IS) sector. Table 1 presents a summary of the main differences between the two sectors that need to be considered.

*Table 1. Comparisons between work performed in the construction and IS sectors**

Issues	Similarities	Differences
Work type	Defined project programmes.	Construction: new/refurbishment). IS: maintenance/repair.
Locations	Defined sites, physical boundaries.	Construction activities linked to build programme. IS activities are longer term.
Workforce qualifications	Mostly trained/competent workers.	Construction: greater range of trades.
Control of Sites	Construction: principal contractor (PC). IS specialist operations also have PC.	IS: established client sites, controlled by the client.
Professions employed	Both include: planners, site managers and supervisors, scaffolders, insulators, painters, mechanical and electrical engineers, welders.	IS: more niche and specialised skilled staff.
Workforce demographics	Personnel with a broad range of ages, genders and ethnicities employed, although predominately male.	IS: employ more UK nationals.
Employment duration	Some tradespersons, e.g. scaffolders, can be itinerant in IS, same as construction.	Employees in IS sector tend to be employed for longer periods of time.

*Based on authors' experience of both sectors

LITERATURE REVIEW

Worker Engagement

The term 'employee engagement' is used to describe employees' emotional attachment to their employer (Byrne, 2012). The indication is that the stronger the attachment, the greater the likelihood that employees will apply more discretionary effort to help their employer achieve their goals and objectives. Hakanen and Schaufeli (2012) suggest that increased levels of WE are linked with improved customer satisfaction, loyalty, profitability, productivity, and improved H&S in the workplace. Wachter and Yorio (2014) specifically looks at the relationship between H&S management practices and WE in the USA resulting in reduced accident rates.

The Health and Safety Commission (now the 'HSE Board') and Construction Industry Advisory Committee (CONIAC) declaration (HSC, 2004) outlines the principles behind the promotion of WE in the construction industry. This acknowledges all workers (not just employees of the main contractor) should be able to participate in the management of health and safety (H&S), based on a culture of 'collaboration and trust'. The intent is to encourage contractors to move beyond a minimum level of workforce consultation to a point where the workforce is fully engaged in the process of H&S management on site.

Cameron et al. (2006) in a research report, *RR516*, commissioned by the UK HSE, describe the development of a continuum for WE, which moves beyond the basic legal requirements of consultation, through stages involving participation and involvement of the workforce to a final state where workers are fully integrated with decisions affecting the workplace. This theoretical continuum ranges from 'command and control' on one end, to full 'independence' of decision making on the other. Although, in reality, the UK regulatory structure is such that employers (or management) need to be seen as having ultimate responsibility for decision making, planning, resourcing, monitoring etc. regarding the management of H&S. Therefore, for the UK at least, this continuum remains somewhat abstract. This work establishes key demonstrable elements of WE: worker knowledge of key risks;



adequate resources to address issues raised; adequate communication mechanisms; and evidence of the WE process actually influencing decisions.

Meldrum et al. (2009) describe four key factors as the independent variables on which WE depends: knowledge and capability to engage, perceptions, attitudes and behaviours, and actual involvement in H&S risk management. Shearn (2004) sets out three major categories for the justification, and potential evaluation, of worker participation in occupational H&S: potential improvements in psychosocial and organisational development, potential productivity and efficiency gains, and ethical and legal imperatives.

Worker Engagement Maturity Model

The concept of maturity measurement for WE is based on frameworks from the United States Department of Defense as a means to characterise the capabilities of software development organisations (Humphrey, 1988). A maturity model can be viewed as a set of structured levels that describe how well the behaviours, practices and processes of an organisation can reliably and sustainably produce required outcomes. The key difference between these former types of maturity models and the Hare et al. WEMM is that the former is conducted from a perspective of measuring organisational capability, whereas the latter is focused on assessing workers' perceptions of the extent of their personal engagement in H&S in the organisation. The WEMM focuses on the five elements of trust, commitment motivation, empowerment, and meaningful discussion. There are incremental properties in each one of these elements; for example, meaningful discussions are evaluated against five levels of criteria based on feedback received from operatives. Level One discussions are concerned with the immediate work area whilst Level Five discussions are concerned with issues beyond the site gate such as design or wellbeing programmes that can have an influence outside of work.

Trust

There is a general assumption that a subordinate's trust in a leader is a positive attribute for organisational effectiveness (Britt, 1999). Research shows that H&S performance is positively affected by trust (Reason, 1997; Watson et al., 2005; Zacharatos et al., 2005). However, research by Conchie et al. (2013) appears to challenge this assumption and notes circumstances where high levels of trust can have a detrimental outcome and distrust can be seen as a positive outcome (Lewicki et al., 1998). So whilst trust can lead to increased WE, it may not lead to H&S improvements. Hare et al. (2017) set out their hierarchy beginning with 'lack of trust' leading to trust in 'ability' (of co-workers) 'benevolence' (of managers) and finally, the highest level of 'integrity' of the company. Trust in ability relates to perceptions of skills and competencies; either how the individual perceives others or how they think others perceive them. Benevolence relates to whether others are perceived to genuinely care for the individual's welfare and wellbeing, whilst integrity is characterised as displaying consistency and fairness, particularly from superiors and by extension, the employer organisation. These elements are drawn from Mayer et al. (1995), but the original application of these three antecedents of trust should be in equal measure, i.e. an individual may perceive trust in ability, benevolence or integrity together or separately – not in a hierarchical framework. It is also described by Mayer et al. as a continuum rather than a binary yes or no. These discrepancies need to be acknowledged when evaluating the WEMM.

Commitment

Commitment can be regarded as a force that maintains or drives obligatory direction to behaviour (Becker, 1960). Commitment has been positively linked to improved job satisfaction, lower levels of absence and increased desire to remain with an organisation (Meyer & Allen, 1991). Meyer and Allen (1991) propose three separate constructs that support the psychology of commitment: continuance commitment, normative commitment and affective commitment. They describe continuance commitment as being cost-based, e.g. if a worker determine that they would lose a benefit important



to them by leaving the organisation, then the extent of their commitment would increase. Normative Commitment is described as a state where workers are driven to remain loyal to the organisation by moral obligations (Meyer & Parfyonova, 2010). In the case of Affective Commitment, there is a strong link between the goals of the organisation and an individual's values and beliefs. The resultant behaviour is described in the literature as organisational citizenship behaviour (OCB) (Smith et al., 1983). Hare et al. align these three constructs with their hierarchy of 'conditional', 'compliance', and 'citizenship' levels of commitment. Conditional commitment is associated with behavioural safety theories, where workers are more likely to be motivated by self-interest and therefore less likely to desire to become involved in H&S programmes, reporting of incidents and acting to resolve an immediate hazard. This aligns with cost-based continuous commitment. Compliance commitment is characterised by doing just enough to stay in the job. In respect of H&S on site, workers who display compliance commitment may support and help each other out, but will not generally be prepared to go beyond achieving anything other than broadly compliant outcomes. This aligns with loyalty-based normative commitment. Citizenship commitment - generally display greater discretionary efforts with regards to H&S - is in full alignment with affective commitment in the same way Safety Citizenship Behaviour (SCB) (Hofman et al., 2003) is aligned with OCB. The literature therefore supports Hare et al. commitment measures.

Motivation

Dejoy (2005) discusses the two main psychological approaches to enhancing work-related H&S performance: behavioural based and culture based. Behavioural programmes rely on incentives and punishments to influence behaviour, whilst culture programmes aim to educate, in an effort to change values. Fleming and Scott (2012) argue that both approaches have been effective in improving workplace H&S performance. These two approaches can be considered as extrinsic (behavioural) and intrinsic (cultural) motivators, as described by Ryan and Deci (2000) in their theory of self-determination, which has been instrumental in providing a mechanism to help understand the influence of motivation on work performance. This is important in terms of H&S performance as Zohar et al. (2015) points out that if employees believe that management recognise (and reward) speed of job completion as being of greater importance than following H&S rules, then lower levels of H&S performance will result. Intrinsic motivation factors help to explain predicted behaviours and task performance in terms of the level of interest that the employee has in the task and the challenge associated with its execution. However, Ryan and Deci include several incremental sub-levels of external motivators, gradually moving towards internal, indicating it is not binary. Jiang and Tetrick (2016) also include 'Amotivation' (lack of or no motivation). Fleming and Scott (2012) present a similar incremental approach to H&S motivation with controlled and autonomous H&S motivation factors. Hare et al build their hierarchical measure for motivation from amotivation, to extrinsic, then intrinsic which is aligned with the supporting literature.

Empowerment

At its simplest, empowerment embraces the idea of employees being provided with increasing flexibility and freedom to make decisions relating to the way their work is performed (Greasley et al., 2005). Conger and Kanungo (1988) describe the perceived advantages of empowered workers, which include benefits to shareholders through improvements in bottom-line performance, improved customer service and employees having a higher-quality work life. However, Appelbaum et al. (1999) also noted concerns about empowerment being wrongly regarded as a panacea for solving management problems as well as the risks that empowerment can present in the form of loss of management control, overconfidence and abuse by those provided with greater authority over how their work should be conducted. Lee and Koh (2001) build on previous research, describing dimensions of empowerment as: meaningfulness; competence; choice and impact. Meaningfulness relates to the individual's own values in relation to the task goal, competence relates to perception of their own ability to perform the task, choice in terms of a sense of autonomy, and impact in terms of perceptions



of overall influence. Hare et al. align meaningfulness with knowing and competence with doing, which they see as the foundations of empowerment in relation to technical and H&S standards and their implementation. Decision making and then influencing sit at the upper end of the Hare et al. empowerment measures, with the former relating to day-to-day tasks and the latter impacting on wider policy, design, and/or management decisions. On the face of it, these measures are supported by the literature.

Meaningful discussion

Tulloch (1993) states that employees who are meaningfully involved will feel ownership of a plan and also of the subsequent implementation activities. Hirumi (2002) helps the understanding of meaningful discussions by adding that if the discussion influences workers' knowledge, promotes curiosity and leads to positive work-related activities, the discussion can be regarded as meaningful. Regarding H&S, Maloney and Cameron (2003) suggest that meaningful discussions will only happen when workers have received training, are experienced and possess relevant knowledge. Jensen (2002) presents research relating to the assessment of workers' participation in legally required workplace assessments in Denmark. The research establishes five inter-related dimensions: 'issues covered' (focus on hazards or more complex causes of risks); 'objectives for solutions' (in terms of hierarchy of controls); 'depth of understanding' (about accident causation); 'scope of solutions' (focus on workers or management and policies); and 'ability to transfer issues' (to higher management for resolution). Cameron et al. (2006) translate these five dimensions into four areas of discussion: welfare; housekeeping; hazard identification; and self-thinking solutions. Hare et al. organise their meaningful discussion hierarchy of measures as: personal work area; welfare facilities; hazard spotting; pro-active solutions; and beyond the site gate (covering policy, design, management issues). This reflects that workers tend to initially focus on their immediate working environment, then wider site issues, whilst some may discuss issues not normally within their remit. This alignment reflects the supporting literature, although it would appear to be more of an interrelated continuum, rather than a strict hierarchy.

RESEARCH METHOD

Rationale

This paper is concerned with two specifics: (1) was the development of the existing WEMM based on valid and reliable evidence and (2) would the model be suitable for use in another sector, namely IS? The literature review generally supports the WEMM, albeit with some qualifications. However, the model was conceived and developed within the traditional project-based construction sector.

Case Studies

The method adopted here was qualitative. Creswell (2014, p. 20) pointed out that qualitative studies are useful when 'the subject has never been addressed with a certain group of people'. A case study approach was selected for reasons best described by Crowe et al. (2011 p. 1), who stated that 'the case study approach is particularly useful to employ when there is a need to obtain an in-depth appreciation of an issue, event or phenomenon of interest, in its natural real-life context'. Three case study sites were chosen due to their contrasting characteristics: Site A (gas processing plant, with different clients over the years); Site B (nuclear power generation site, with same client for 40 years); Site C (petrochemical site, with a high turnover of staff).

An initial review of the questions used in the WEMM was undertaken by an expert panel of industry H&S practitioners and academics. The panel recommended some minor changes to the existing questions to ensure they were able to be understood by workers in the IS sector. The next step was to use these amended question sets in a pilot study to determine their effectiveness before embarking on the main data gathering exercise. This replicated the method used by Hare et al (2017) to ascertain if similar results could be achieved with IS workers, i.e. use their answers to establish their

engagement level. The sampling was undertaken purposively with instructions being provided to site managers to help them select workers who were either highly or moderately engaged in H&S. Data was gathered from 12 employees (limited by time and resource constraints) across three different sites, peer debriefing and feedback from the expert panel subgroup, and member checking where the interviewees were asked to review the themes generated from their interviews to determine if they aligned with their spoken intentions. Data was captured and analysed using the NVivo software package. The workers lived experiences were mapped to the WEMM measures. If the WEMM is valid and reliable, the data should confirm if the worker is 'moderately' or 'highly' engaged.

WEMM Questions

Table 2 lists the amended question set used subsequent to the expert panel review.

Table 2. WEMM Question set for IS

Questions
Trust
Who on site do you think is competent when it comes to H&S
Which workers on site do you think work to the same H&S standards as you
Do you think your abilities and opinions are recognised
Do you think management wants to keep you safe and healthy
Would you raise task-based H&S issues with your managers or supervisors
How often do management do what they say regarding H&S
Commitment
Explain a situation related to your task that has prevented you working safely
Describe what you do when you see something unsafe outwith your work area
How active are you about promoting H&S on site
Describe something you have done recently to improve H&S
Describe any situations where you feel you couldn't trust your co-worker or supervisor
Motivation
Is there anything you would put before H&S
Is there anything your manager/supervisor would put before H&S
Describe the reasons why you might work safely
Describe the reasons why your manager or supervisor expects you to work safely
How does working safely make you feel
Empowerment
Describe what you need to carry out your task safely
Describe how you are supposed to do your work safely (for a specific task)
Describe what training you have had that helps you work safely
Describe a time when you had to solve a safety problem
With H&S in mind, describe how you plan your work
In terms of planning, what opportunities do you have to influence decision making in terms of H&S
In practical terms, what opportunities do you have to influence, how the work is undertaken
What response have you had from site management regarding your suggestions
Meaningful discussion
Do you speak to your manager/supervisor about Health and Safety
What H&S issues do you discuss with your manager/supervisor

RESULTS

Data

For ease of representation, the data is presented using percentage scales to represent each level of each element of the WEMM model i.e. the meaningful discussion measure has five levels in 20% increments, trust has three levels in 33% increments. Each element is displayed in a radar graph with individuals represented with a sequential number. The points on the graph show maximum and minimum scores for each individual, illustrating that their responses resulted in a range of answers when compared to the measurement criteria.

Trust

Figure 1 shows that all four levels of trust were observed amongst the sample. A difference from the original WEMM measure is that trust in ability was sub-divided into 'self', 'other co-workers' and 'supervisors'. Under the original WEMM, all 12 workers would have scored the highest level. However, the introduction of high/low shows that workers trust some people but not others. Lack of trust was reported in relation to supervisors and other contractors' workers.

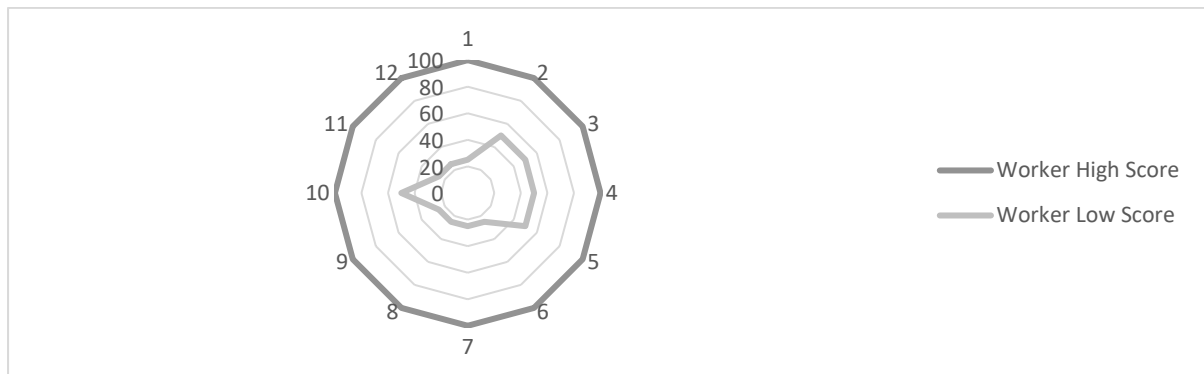


Figure 1 Trust response range

Commitment

The results for commitment were very consistent, demonstrating higher levels than those reported by Hare et al. from the construction industry. Only one worker reported a minimum level of 1. This shows that all workers in the sample want to do the right thing regarding H&S and were able to demonstrate it through describing their actions. This data has its limitations compared to direct observation of behavior, but it must not be looked at in isolation and workers' responses can be compared across all measures. Non the less, this measure shows the sample to have high caliber 'citizenship' levels of commitment, whether they were considered moderately or highly engaged.

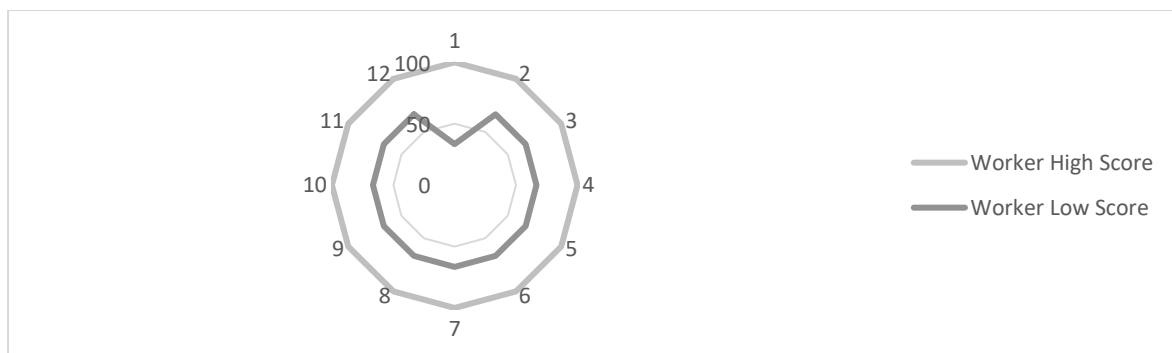


Figure 2 Commitment response range

Motivation

The range of responses (see Figure 3) revealed that all of the workers achieved the highest score and provided interview extracts that were coded against intrinsic motivation. This result is similar to the previous 'commitment' measure and again indicates strong engagement characteristics amongst the sample. Worker number 10 was identified as highly engaged by management, this being the only indicator so far in the analysis that confirmed the same.

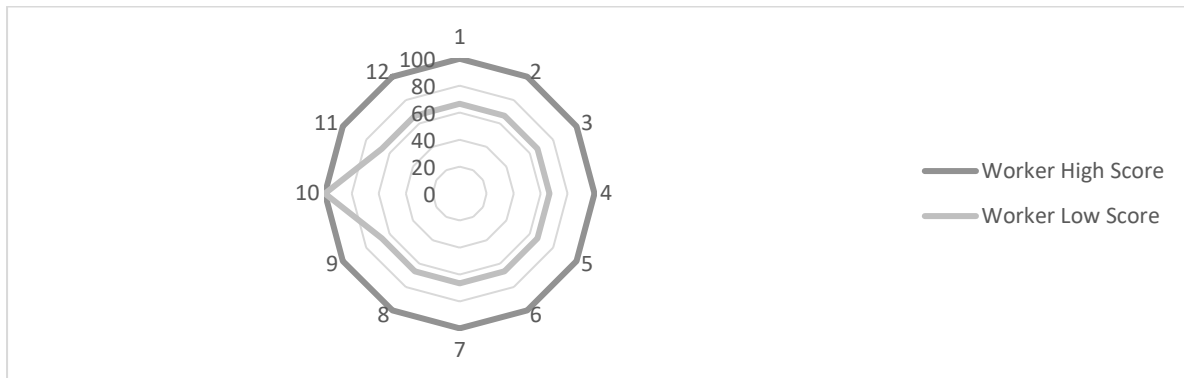


Figure 3 Motivation response range

Empowerment

Figure 4 shows that all workers in the sample feel they are competent and can demonstrate it through describing their work tasks in detail. There is only small variation in the higher levels, where differing levels of influence were related to the worker's views on how taking their own initiative is not encouraged. This is understandable as improvisation is considered a cause of accidents but should not be used to stifle innovation. There was not enough variation to determine those identified by management as highly engaged.

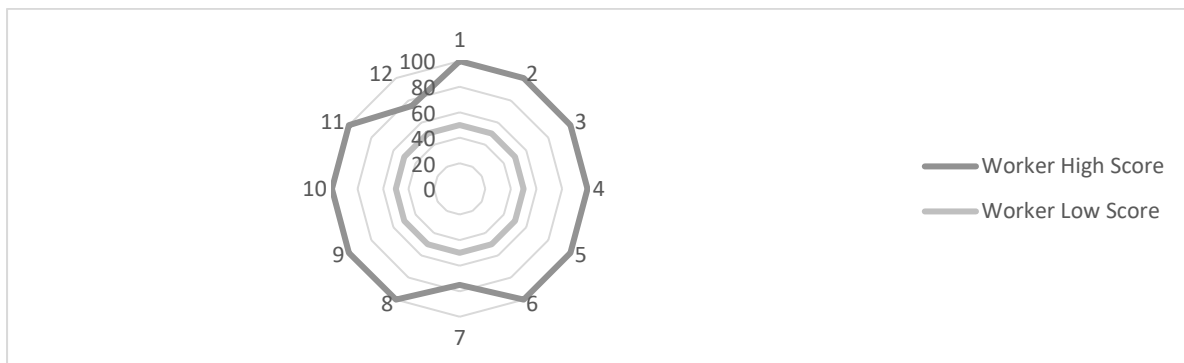


Figure 4 Empowerment response range

Meaningful discussion

Figure 5 shows the element with the most variation. Analysis of the interview data showed that nine out of the 12 workers interviewed were categorised as highly engaged, whilst the remaining three workers were classified as moderately engaged. Those same three workers were judged by their management to be moderately engaged. However, three other moderately engaged workers were in the nine demonstrating high levels in Figure 5. This graph shows that there is room for improving the subject matter that is discussed but does not align with management judgments of who is highly or moderately engaged.

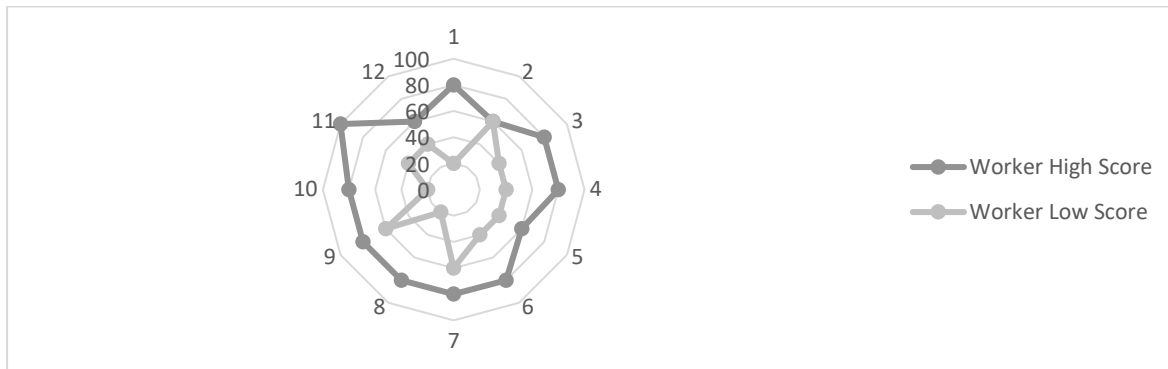


Figure 5 Meaningful discussion response range

CASE STUDY INFLUENCES

Site C had the smallest number of workers (40) employed by the contractor and overall there were fewer employees from other contractors. Site A had, on average, 60–80 workers directly employed by the contractor. On this site there were several hundred workers employed by other contractors or directly by the client. Site B had approximately four hundred workers employed by the contractor and on the whole site there were several thousand workers. When measuring the number of coding references, Site C demonstrates greater levels of *intrinsic motivation* and belief in the *integrity* of the company. They had more discussions about *proactive site solutions* and provided more examples of empowerment and *citizenship commitment*. Site C workers also demonstrated the greatest level of trust in co-workers and managers/supervisors. A potential explanation for the higher levels of engagement at Site C could be that it is a smaller site where the workers know each other and their supervisors and management more intimately. Also, workers' comments indicated that they felt that their site manager and the client staff were approachable and considered H&S as a high priority.

CONCLUSION & RECOMMENDATIONS

Although the study reported here has used a small sample, the qualitative data was voluminous. Most of this cannot be reported in this paper. In general, the results of Hare et al. from the construction sector have not been replicated for the IS sector. Workers in the IS sector are generally long-term, permanent employees who have been inculcated in the organisation's approach to H&S and are therefore more likely to already be highly engaged. None the less, the literature does support the choice of criteria in the WEMM and modifications to the question set reported here makes it useful for identifying opportunities for improvement. The original WEMM sought to identify the highest level of engagement maturity, but it is equally important to map the 'range', i.e. the extent, of workers' responses from the lowest to the highest level. By reviewing the range of responses, it is possible to identify any gaps in engagement so that tailored improvement plans can be developed.

Further iterations of the WEMM in other sectors is recommended, as the study reported here shows that repeating the method helps to develop the criteria, and the updated question set should be adopted for future use of the model. A digital tool (as recommended in the original WEMM work) could easily be developed to gather, analyse and compare WEMM within and across industry sectors.

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Cultivating a 'just' culture in construction industry to improve Health and Safety management systems

Meri Duryan, Jing Xu, Hedley Smyth

The Bartlett School of Construction and Project, UK

Correspondence: m.duryan@ucl.ac.uk

ABSTRACT

Within the last decades, safety statistics in the UK construction industry have reached a plateau and cultural changes are required for further improvement of occupational health and safety (H&S) management systems. The aim of this research is to understand how the UK construction industry can improve H&S reporting to learn from failures and near misses based on experience of aviation and aerospace industries that made a successful shift from a 'blame' to a 'just' culture. The reason is that H&S culture remains undeveloped within the industry. Cultivation of a culture that can facilitate bottom-up reporting and learning from failures and near misses is difficult due to fragmented nature and the complexity of construction programme and project operations. The industry that is criticised for being inward looking and slow in learning could benefit from safety practices of other safety-critical industries, rather than take a position of its uniqueness. An interpretative methodology is applied in this research. Thematic analysis is supported by cognitive mapping technique. The findings revealed that H&S practices in the construction industry are affected by the lack of consistency across construction sites due to fragmented supply chain, 'silo' project culture and a tendency to blame individuals for human error. The levels of engagement with bottom-up reporting are quite low and the most frequently mentioned reasons are transactional approach to H&S by the management, figure-pointing behaviours, lack of robust follow-up processes and lack of trust. H&S regulations, norms and guidelines do not include all possible safety issues specific to unique project environments. Cultivation of a 'just' culture could help the industry to go beyond H&S legal compliance and change attitude to safety reporting. Despite the differences, construction organisations can learn from aviation and aerospace industries' accountability for the systems they design and from their proactive approaches to dealing with human error and encouraging and facilitating self-reporting.

Keywords: Health and Safety, Construction, Culture, Management System, Organisational Learning.

INTRODUCTION

The UK construction is a complex safety-critical industry that involves a wide range of enterprises that form long supply chains (Office for National Statistics, 2018) and operates under the pressure to deliver short-term results, which affects the management of occupational H&S. Moreover, the industry is known for having an orthodox approach to H&S on sites and for 'finger-pointing' behaviours that discourage employees to report near misses and failure or raise concerns regarding fatigue, stress, and other H&S issues.

Given that safety statistics have reached a plateau (HSE, 2018), the limitations of transactional approach to H&S are starting to be acknowledged by the industry. Identification of root causes and quantification of risks with the following reduction of accidents via technological and administrative interventions is not sufficient anymore and a deeper analysis of the causes of injuries and fatalities that mainly lie in the behavioural or cultural domains is required (e.g. Goh, et al., 2018).



There is no one-size-fits all model for H&S systems. Given that most incidents are combinations of organisational, cultural and human factors, construction organisations need to move away from buck-passing and fear of blame to facilitation of bottom-up reporting and learning from failures and near misses, followed by analysis of contributing factors along the causal chain (Carrillo et al., 2013; Dekker, 2009; HSC, 1993; HSE, 2005).

The focus of this paper is improvement of safety reporting systems to learn from failures and near misses based on experience of aviation and aerospace industries that made a successful shift from a 'blame' to a 'just' culture. Empirical data are gathered through semi-structured interviews with H&S policy makers, H&S specialists from aviation, aerospace (aircraft maintenance) and construction industries, academics, and programme managers from large infrastructure organisations. The findings demonstrate inconsistency in H&S culture and the lack of a systematic approach to learning from incidents, failures and near misses in the UK construction industry. The industry needs transformational change in a legal framework and in policies and procedures that will support non-punitive reporting of incidents. Based on the perceptions of the respondents, the industry needs to improve upon arbitrarily punitive policies and create an environment in which individuals are encouraged to report near misses and failures.

LITERATURE REVIEW

Safety culture

International Nuclear Safety Advisory Group's summary report that reflected on lessons learnt from the Chernobyl accident, initiated debates on safety culture (Guldenmund, 2010). The concept 'safety culture' is used to illustrate how organisational culture, among several other factors, influences H&S behaviours (Antonsen, 2009). Safety culture reflects beliefs about what is 'right' or 'wrong' within the organisation (HSE, 2005). Depending on an established culture, organisations whether blame individuals for human error and discourage people from reporting incidents and near misses (HSE, 2005) or create an environment where employees share perceptions of the importance of safety and build their confidence in the efficacy of preventive measures they can contribute to (HSC, 1993). Schein (2004) clinically analysed and prescribed safety culture in organisations of extreme high risk to address the H&S.

Safety culture "evolves gradually in response to local conditions, past events, the character of the leadership and the mood of the workforce" (Reason, 1998). It depends on a number of interacting elements in organisations, including ways of doing, thinking and managing. According to HSE report (n.d.) on safety culture, there are key factors that define its efficiency and effectiveness: management commitment, visible management, good communication between all functional levels, and active employee participation in safety reporting. 'Safety reporting culture' and a 'just culture' are two of the most important aspects of safety culture (Reason, 1998).

The 'just' and 'safety reporting' approach

According to Reason (1997), a 'just' culture is about safety thinking that is based on a questioning attitude. It promotes double-loop learning, learning that comes from people questioning their assumptions and beliefs. A 'just' culture acknowledges that human error is inevitable and human adaptability is needed to deal with local circumstances. Even experienced professionals can violate routines, use shortcuts and workarounds. At the same time, a 'just' culture does not accept reckless behaviour and lack of responsibility and accountability and posits that better communication and more transparency on punitive matrix increase staff awareness and promote free reporting (Dekker and Breakey, 2016).



Some studies on the relationship between safety culture and safety performance demonstrate that employees' involvement in unsafe acts and accidents is linked to their perceptions of safety policies (e.g. Clarke, 2006). To encourage people to provide information on failures and near misses, organisations need to be open on the boundaries between culpable (or acceptable) and non-culpable unsafe acts (GAIN, 2004; Reason, 1997). It is quite challenging though for organisations to distinguish between the two; a case-by-case review of an incident is required. Organisations need to evaluate their safety processes and procedures to ensure that there is a system in place to learn from incidents that are reported openly and communicated back to employees (GAIN, 2004). The leadership needs to be ready to reconfigure the organisational structure to adjust to the changing task environments (Parker et al., 2006). According to Dekker (2009), organisations should see near misses and incidents as opportunities for collective learning. They need to promote a questioning attitude and foster personal accountability and corporate self-regulation in safety-related issues (GAIN, 2004). Employees should be rewarded for H&S reporting at early stages (GAIN, 2004; Parker et al., 2006).

Modern aviation safety management systems SMS serve as decision-making tools that aim at eliminating known and unknown risks. Aviation SMS, that were developed on the basis of quality management systems, put emphasis on designing a quality system with repeatable processes along with measuring performance and are supported by the organisational culture of error reporting (Dekker, 2009; Stolzer and Goglia, 2016). Aviation SMS are based on four structural elements: safety policy, safety risk management, safety assurance, and safety promotion (Stolzer and Goglia, 2016). Safety policy refers to the dedication by senior management to cultivate a 'just' culture in which reporting on failures and near misses is considered as a normal behaviour, and in which organisations are accountable for systems they design, rather than individuals.

There is a strong belief in the industry that punishing employees for making mistakes will not stop them repeating those mistakes. The benefits of a 'just' culture include (GAIN, 2004):

- Increased reporting - to address latent safety problems (among other things).
- Building trust - one of preconditions of a 'just' culture.
- Effective safety and operational management.

Aviation industry puts significant efforts at eradicating blame and positively encouraging reporting. The industry acknowledges that people at the frontline are not usually the instigators of accidents and incidents, they normally inherit challenges that have been already in place or were developing over a long period (e.g. Reason, 1997).

Health and safety culture on construction sites

The UK construction industry is a complex industry with over 314,590 organisations (Office for National Statistics, 2018) that operate in high-risk operational environments, which calls for more attention to occupational H&S. However, due to the pressure to deliver on time and within the budget, any changes in the project performance goals may affect the priority of safety. Lately, closer attention has been paid to the concept of H&S culture in the industry (e.g. Sherratt et al., 2013) leading to a significant decline in injuries and fatalities on construction sites. However, the rates of decline have slowed within the last decade (HSE, 2018), suggesting there is a need for a deeper analysis of the causes of injuries and fatalities that mainly lie in the behavioural or cultural domains (e.g. Goh, et al., 2018).

Cultural change is especially necessary for construction organisations because they are multi-level systems with variations in safety perception and quality of implementation (e.g. Zhang et al., 2018). Construction projects are complex technologically and culturally as they are shaped by the groups of professionals from other organisations across the long and complex supply chain (Duryan et al., 2020; Walker, 2015), which complicates building relationships of trust and cultivating a culture that



encourages safe behaviours. Cultural silos are created even when “all contributors are in-house to the client organisation” (Walker, 2015, p. 161). This implies that safety on construction sites may depend on the management team working on that specific site, rather than on the company itself, and line managers’ commitment to safety may have a strong influence on employees’ safety behaviours (Duryan et al., 2020; Schein, 2004). However, top-down approach to managing H&S in construction is focused on regulating employees’ behaviour through the enforcement of prescriptive rules and procedures without consideration of the role that different cultures in a single organisation play on safety behaviours.

Among other factors, ‘blame’ and ‘macho’ cultures are seen as a major obstacle to safety behaviours (Duryan et al., 2020; Goh et al., 2018). Some work environments in the industry involve ‘macho’ role models, which inhibits raising concerns regarding fatigue, stress, and other H&S issues (Goh et al., 2018). This is especially dangerous on the labour-intensive construction sites, given that fatigued and stressed workers are more likely to have accidents and injuries (Sherratt et al., 2013; Smyth et al., 2019). To promote greater introspection and analysis of failures and near misses a cultural shift from buck-passing and fear of blame to learning from success and failure is required (Carrillo et al., 2013; HSE, 2018). This highlights the importance of cultivating a ‘just’ culture to encourage bottom-up reporting, learning from incidents, near misses and failures internally and across the long and complex supply chains. Not only management strategies and actions are needed to consider the traits of organisational culture that can affect efficiency of formal and informal H&S practices (e.g. Roberts et al., 2012), but also collective H&S norms should be established to guide people in their daily decision making. The industry needs to benchmark its safety practices against other safety-critical industries, rather than take a position of its uniqueness (Duryan et al., 2020). Significant changes are also required in a legal framework and in policies and procedures that will support non-punitive reporting of incidents.

METHODOLOGY AND METHODS

This paper is drawn from wider research on the impact of Digitisation and Digitalisation on Occupational Health and Safety and Wellbeing in construction industry in the UK. The focus of this paper is improvement of bottom-up safety reporting to learn from failures and near misses based on experience of aviation and aerospace industries that made a successful shift from a ‘blame’ to a ‘just’ culture. An interpretative methodology was used in this research (e.g. Miles and Huberman, 1994). A total of 49 interviews with representatives of construction clients, main contractors, subcontractors, sector investors and consultants (programme managers, H&S managers, engineering directors, operations managers), aerospace and aviation organisations (crew members, technicians, production and H&S managers), representatives of policy implementation bodies and academics, were conducted across two research phases: pilot interviews and main interviews. There were differences in the questions asked based on the types of organisation, however, all themes included questions on the key leverage points required to break through the statistical plateau in occupational H&S, H&S reporting, lessons that can be learnt from aviation and aerospace industries, particularly on safety culture and safety behaviours.

Thematic analysis of the data from the interviews was enhanced by a cognitive mapping technique that allowed understanding of interrelationships among the concepts expressed by the respondents. The cognitive mapping technique helped to demonstrate both the complexity of the findings and rigor in the analytical process. A cognitive map, a two-dimensional directed graph that represents the issue from the perspectives of an interviewee, is a visual representation of the mental models within the human mind. It is grounded on cognitive psychology and facilitates understanding why a situation is problematic and what can be done about it (Eden, 2004). The concepts in the nodes are expressed in the interviewees’ own language and the meaning of every concept is contextual. In this paper, the

head, domain and centrality analyses of the merged cognitive map were conducted to identify the goals and key strategic directions as perceived by the respondents.

RESULTS AND ANALYSIS

The cognitive mapping technique enabled structuring of shared beliefs of all interviewees regarding the importance of a 'just' culture for H&S in construction industry. Given the complexity of the map (226 nodes), a more simplified schematic map is presented (Figure 1) to demonstrate how the analysis and relevance of the findings were derived. The heads of the map, the goal-type statements, are the concepts represented by the nodes that have only arrows going inside.

The analysis of the cognitive map revealed the key strategic directions (as perceived by the respondents) that contribute to the head of the map (the goal), which is "improve health and safety and wellbeing in construction industry" (Figure 1). The key strategic directions (the concepts with the highest domain and centrality scores) are the heads of clusters, groups of concepts that are linked together and cover a specific area of the issue (the underlined nodes, Figure 1). The links among the clusters indicate their interrelatedness (dotted arrows, Figure 1).

Cultivating a 'just' culture

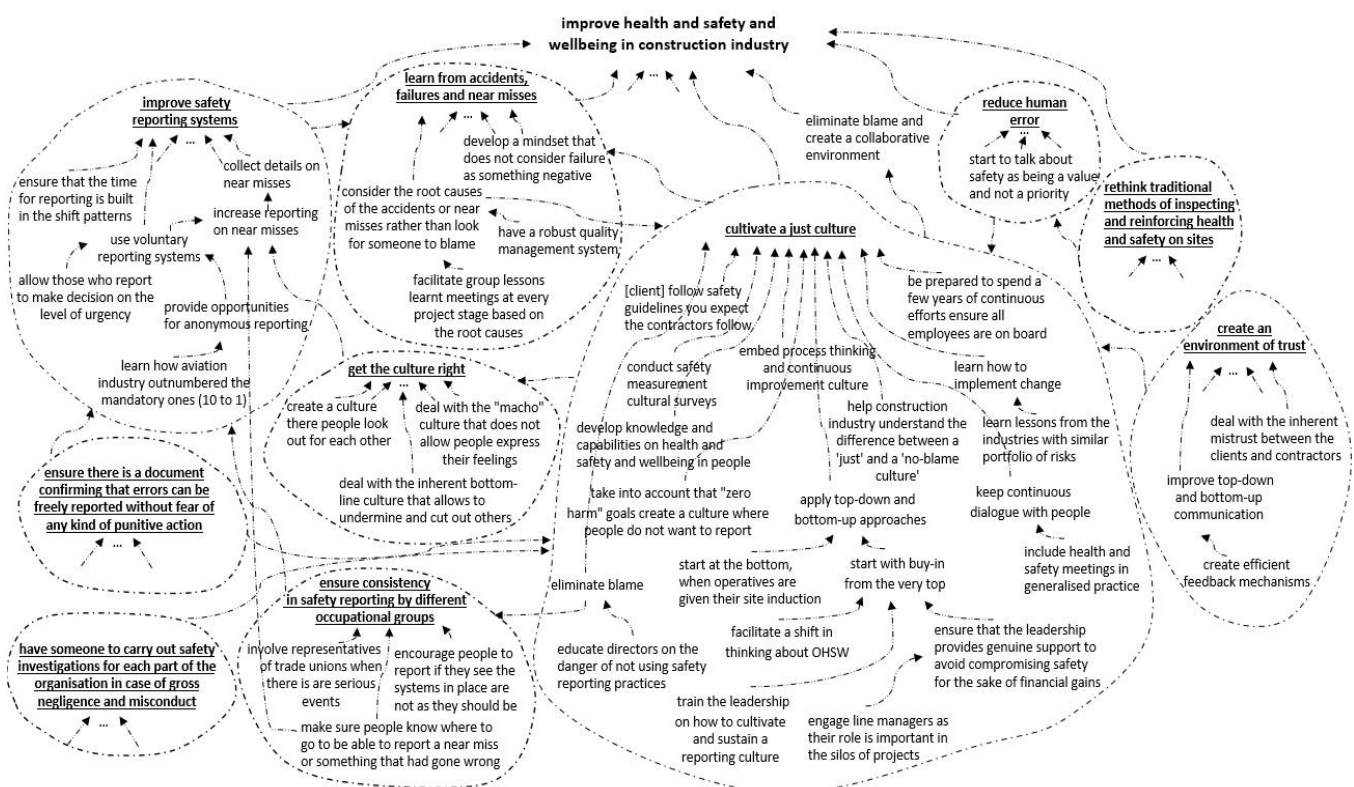
Overall, the interviewees from construction industry see 'blame' as one of the major obstacles to safety reporting. The H&S director of a real estate company mentioned that:

...the construction world is still very masculine; it is still quite macho. And however hard we work, we are still battling...

Based on the analysis of cognitive map, the cluster 'get the culture right' (Figure 1) has an immediate impact on the rates of reporting on near misses. 'Macho' culture inhibits also reporting on health-related issues, which eventually affects employees' wellbeing. This is especially evident in smaller organisations:

[construction industry] is very gung-ho get the job done. It is very macho... if somebody is not feeling well one day they will get ridiculed...

Figure 1: Schematic merged map





Organisational culture needs to encourage people to report not only on near misses or failures, but also on health-related issues knowing that they will be handled “discreetly, sensitively and for the greater good of all those concerned”. According to a construction safety manager, one of the reasons for finger-pointing behaviours can be the lack of the mechanisms to consider all factors that contribute to incidents and near misses:

... we take in on a face value and we look into the factors bringing the event, fine. How about the surrounding factors because they influence the outcome? That is where information is omitted, so immediately they find someone to blame, because it's easy.

The respondents from policy makers highlighted the need for a major cultural shift in the industry to ensure that safety policies work. The interviews revealed also that there are some pockets of good practice in the industry. There is a “real appetite in the bigger companies to learn from their mistakes”. Unfortunately, this does not relate to the smaller companies that largely do not have enough resources to invest in H&S:

... it's all about making money [in small companies]. Unfortunately, these smaller companies are the ones where somebody will fall off a scaffold or fall off a roof... [they] are probably going to be the biggest risk of not improving.

Another responded from the industry mentioned that senior managers and site supervisors need to display safety behaviour. Only in that case, “slowly but surely” organisational culture will change.

Learning from accidents, failures and near misses

According to the respondents from aviation, the industry regularly conducts “human factors and continuation” trainings where they also learn from incidents. As the air maintenance manager mentioned, there is a “a hunger, almost a morbid interest in some ways, to understand what went wrong” in the industry. Based on the priority given to organisational learning among the key emergent issues (the concepts with high centrality and domain scores), the respondents agree that more proactive approach to lessons learnt should be taken. According to a construction H&S manager:

Lessons learnt is a reactive thing. We are waiting for something to happen and then we will learn the lesson. We actually need to look ahead and say... “What else can we do to drive improvement?”

From the perspectives of the respondents, some of the main differences between the construction and aviation industries are lack of consistency across construction sites and uniqueness and complexity of project operations, which means that H&S related solutions must allow for customisation. Thus, organisational learning on H&S in construction industry cannot be complete if it is based on generic safety guidelines and regulations (e.g. Duryan et al., 2020). According to an H&S manager:

... there's nothing worse that somebody saying, “Follow this process,” and actually half of it doesn't relate to you.

Safety practices are context specific and to be successful they need to be grounded on knowledge-based reasoning (e.g. Duryan et al., 2020). Employees at the sharp end need to develop experience and cognitive skills to act appropriately when dangers arise. This requires organisational support from the knowledge management systems at project and firm levels.



It emerged during the interviews with the representatives of construction industry that not only 'blame' but also 'silo' mentality is a major constraint to organisational learning on H&S. The industry needs to develop mechanisms to transfer H&S knowledge across functional silos and boost collaboration and learning (e.g. Duryan et al., 2020). Based on the interviews with the representatives of aviation and aerospace industries, one of the reasons for their success in cultivation of a 'just' culture was breaking down functional silos.

Safety reporting

The levels of engagement with reporting are quite low in the construction industry and the most frequently mentioned reasons fall into two related categories: blame and a lack of trust. From the perspectives of the respondents, cultivation of a 'just' culture has a direct link to changing attitudes towards failure and near misses (Figure 1). Construction projects are pressured to get the job done on time and within the budget to move onto the next contract and so, the concept of failure is not seen as a way to learn and improve SMS. The H&S manager from aerospace industry highlighted the importance of going beyond H&S legal compliance to change the attitudes to safety reporting:

... it is important not to get tied down with showing that you're complying and ticking boxes, to make sure everything is green... if they're reporting something that is red, then it shouldn't be seen as a bad thing. It should be, "Yes, it's red. Why is it red? How can we help you return to green? What do we need to do to make sure that it's safe?"

The management of construction organisations, and this is especially relevant to the client organisations, need to shift their mindset from seeing 'red' on a safety scorecard as a negative thing to seeing it as a product of open and honest reporting.

H&S managers from aerospace industry mentioned that people are encouraged to report not only incidents and near misses, but also inefficiencies and things that cause unnecessary work and workarounds. There is also a structured system that feeds all captured reports onto an intelligent information management system for further analysis. When somebody in the industry reports a near miss or mistake:

...rather than the organisation looking to punish them, it would take that learning, and say, "Actually, if that person did that wrong, could it happen to somebody else? What factors were involved? Were there limitations because the person was tired?..."

The industry has a team of people that are trained to undertake these investigations. They analyse the factors that caused a near miss or incident. If necessary, they conduct interviews with the people involved and with the witnesses, so all the causal factors will be considered.

The voluntary reporting in aviation feeds into leading indicators and predictive capacity. The philosophy behind encouraging voluntary reporting, that is correcting small failures to help the industry stop more serious incidents, proved to be efficient. According to the manager of the centre for safety and accident investigation, the voluntary reports outnumbered the mandatory ones ten to one. One of the cabin crew members emphasized the importance of a 'no blame' in the corporate culture for cultivating a voluntary reporting culture:

I've never thought that reporting will result in blaming me. It never happens... For us, the reporting only results in benefits, that is everybody's safety.

H&S experts from aviation and aerospace industries highlighted the importance of involving trade unions, who should be seen as partners. Every change in monitoring and reporting, like using drones, is discussed with the trade unions.



Reducing human error

It is normal for all people, including experts, to make mistakes every day. It is noticing the difference between the behaviour we want and the behaviour we get that helps us learn and refine our decisions and actions. The real problem in safety-critical industries is that some mistakes have such serious consequences that they need to be caught before they have a chance to develop into disasters. One of the construction H&S inspectors mentioned that the real challenge is that:

...the methods of inspecting and enforcing health and safety on sites still do focus far too much on the immediate risk of somebody getting hurt ... they don't necessarily follow through with enough effort to transform the employer. We hope that employers learn from that experience, but whether they do or not is a bit hit and miss in practice.

This affects how organisations deal with human error (see also Figure 1) and cultivating a culture of self-reporting is necessary for people to be encouraged to report as soon as they either have made an error or feel that they have been put in a position where they could make an error. They should be encouraged also to report if they recognise that the systems that are in place are not robust as they should be.

Aerospace industry has an error management system within the H&S management system. As the head of maintenance mentioned, there are several causes that come together to manifest in a potentially catastrophic accident, and knowledge about those causes is of a high importance for the industry. Thus, it is necessary to assure employees that they are “absolutely authorised to hit the stop button and break the links in the chain to prevent that accident happening”. The industry brings human factors into the aircraft maintenance environment to prevent errors. For instance, there are certain things that people are not allowed to do at 2:00 am or 3:00 am because of estimated poor physical performance of human body affected by circadian rhythms. As the same manager mentioned:

... we are very mindful of the time and the impact on the human body and performance, and that gets taken into consideration.

He also acknowledged that there is never one single thing that is gone wrong, normally, it is a chain of events that leads to an accident or incident. Thus, the industry considers all possible contributing factors and puts in as many safety gates as they can with the aim to minimise occurrence of incidents.

Safety leadership

Establishing a safety culture at the organisational level requires commitment from the senior leadership, who are responsible for establishing a fair and just environment and empowering people to report all critical H&S related issues. They have a significant role to play in shaping organisational culture through the messages they convey (Schein, 2004). To sustain a ‘just’ culture and encourage reporting, employees need to have confidence in the leadership. People need to see that there is an effective safety culture and that they will not face punitive actions for self-reporting. As the manager of the centre for safety and accident investigation in aviation company said:

...if leadership are coming in with that hire and fire attitude, "He made a mistake, I want him out," you are going to destroy your 'just' culture...

He mentioned also that senior managers need to communicate the message:

We want to learn about your errors, but you will not face punitive action for reporting your own errors.



The leadership needs to provide “genuine support to avoid compromising safety for the sake of financial gains” (cluster ‘cultivate a just culture’, Figure 1). H&S can sometimes be seen by the leadership of construction industry as an add-on. Some senior managers buy into it with the following investment and support, but not all of them commit. There was a consensus among the majority of the interviewees on the necessity of training the leadership on how to cultivate and sustain a reporting culture. They need to understand the danger of not using safety reporting practices (cluster ‘cultivate a just culture’, Figure 1).

Aviation industry systematically conducts surveys (of about 20 questions) to understand how employees feel about SMS and if they get enough support from the leadership. As it can be seen from the map (cluster ‘create an environment of trust’, Figure 1), the interviewees agree on the impact of top-down communication on trust.

An environment of trust

There was agreement among the respondents from the construction industry on the transactional mode of H&S management. One of the safety managers mentioned that there are instances where people were:

...pushed to do things at speed, rather than always ‘safety-first’. You hear a lot of ‘safety-first’... ‘home safely’, but it has to be more than lip service, it has to be demonstrated from the top.

Based on the responses from the construction industry, there is little trust from the site workers that the employer is really interested in their health and wellbeing, which affects bottom-up reporting. Employees at the sharp end need to know that they will not be unfairly blamed when they report near misses or failures and that they can escalate H&S issues at any time. The approach to H&S reporting in aviation industry demonstrates that a culture of transparency, communication and honest reporting removes a major set of employees’ concerns related to unjust proceedings against them in the event of an accident. A ‘just’ culture helps them see that organisations are concerned with their legitimate interests.

There is a need to build trust not only internally but also across the long and complex supply chain. The interviews revealed that there is a major concern among construction clients for H&S compliance among contractors and subcontractors. There is a bottom-line culture in the industry that is deeply rooted in all the disciplines and all the tiers (cluster ‘get the culture right’, Figure 1). The approach of main contractors to H&S is mainly procedural and prescriptive. However, the interviews revealed that some of the contractors started investing in their H&S teams because they came to realise that “if they can get them performing well in H&S, they will perform well in other areas of managing risk”.

The primary difference in aviation industry is that the supply chains are integrated in general and for H&S. One of the respondents from the aerospace industry mentioned that:

We have to treat the same safety methodology and the same safety culture in my supply chain. Because if a part that my team buys and procures for the aircraft maintainers to fit to the aeroplane, if we don’t make sure it’s safe at source and that we’re buying from an approved supplier, and that that part or that component or that asset meets all the right requirements, then we deliver a hazard to the maintenance organisation, that is going to install that part.

CONCLUSIONS AND RECOMMENDATIONS

This study contributes to the current understanding of key enablers and inhibitors to cultivation of a ‘just’ culture in construction industry to improve H&S reporting. The interviews revealed that the



reporting culture in the industry contrasts with the 'just' culture in aviation, that is free of finger-pointing behaviours and buck-passing. The industry needs changes in a legal framework and in policies and procedures that will support non-punitive reporting of incidents. The methods of reporting need a revision to avoid ambiguity or safety data, improve accessibility or the means of reporting, support professional handling of accident investigation and ensure robust processes for the transfer of lessons learnt. The processes for determining follow-up action need to be revisited as well, because people will not be encouraged to report if they receive no adequate feedback from the management. There is a need to establish agencies or departments that will analyse the industry reports with the authority to initiate disciplinary measures and impose sanctions (GAIN, 2004).

The findings demonstrate that there are pockets of good practice in managing H&S in some larger industry players. However, the lack of supply chain integration remains a major issue for improvement of H&S management in construction. Of course, aviation and aerospace industries are a lot less fragmented, however there is still a considerable opportunity for construction to learn lessons from these two sectors to cultivate a 'just' culture in which bottom-up reporting on failures and near misses is considered as a normal behaviour. The management of construction organisations, and this is especially relevant to the client organisations, need to understand the danger of seeing H&S as an add-on and compromising safety for the sake of financial gains. Addressing this shortcoming could provide a basis for improvement, especially where H&S statistics have plateaued.

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Elevated Injury among Latino Workers in Small-Scale Residential Construction: Contractor and Worker Perspectives

Joseph G. Grzywacz¹, Shannon C. Montgomery¹, Antonio J. Marín¹, Elsa Nuñez-Reyes¹, Thomas Mills², Michael J. Merten³

¹ Human Development & Family Science, Florida State University, USA, ²Myers-Lawson School of Construction, Virginia Polytechnic & State University, USA, ³ Child, Youth and Family Studies, University of Nebraska, USA

Correspondence: jgrzywacz@fsu.edu

ABSTRACT

Purpose. The desired outcome of this study was actionable information that could be converted into intervention strategies that could be deployed with immigrant Latino construction workers in small-scale residential construction and the constructors who employ them to reduce construction-related injuries.

Design. Qualitative data obtained from semi-structured in-depth interviews with n=7 immigrant Latino construction workers in small-scale residential construction and n=5 immigrant Latino contractors in small-scale residential construction were coded and analyzed.

Findings. There was substantial overlap between workers and contractors in the causes of common injuries in small-scale residential construction. There is a general lack of concern with safety attributed to human nature (i.e., That's Just the Way We Are; We're Careless). Safety's relative priority is further diminished by a desire for workers and contractors to make as much money as possible in the shortest amount of time.

Limitations. These data were obtained from workers and contractors in a single urban setting in the southern, midwestern region of the United States. Although the data comport with beliefs reported by immigrant Latinos in other sectors of the economy, the generalizability of the results in the construction industry is unknown.

Implications. These data indicate that small-scale residential construction contractors, like their workers, place a premium on finishing jobs quickly as a matter of keeping their business going. The data also demonstrate an undeniable need to include both workers and small contractors in strategies to improve safety in small-scale residential construction.

Keywords: Accident; Behaviour; Immigrant Latino Workers; Qualitative Research; Safety Education

INTRODUCTION

The disproportionate burden of poor occupational health in construction by immigrant Latino workers is well-documented (Dong et al. 2014; Dong, Men, and Ringen 2010; Dong and Platner 2004). In response to Brunette's (2004) call, several researchers have documented clear and consistent themes that likely contribute to the elevated risk of injury in the immigrant Latino workforce. Research commonly documents that immigrant construction workers work fast and put the speed of work over safety (Arcury et al. 2014; Flynn, Eggerth, and Jacobson 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011). Limited job opportunities for undocumented workers have been reported to contribute to excess injury by impeding concerns over safety (Menzel and Gutierrez 2010; Roelofs et al. 2011). Moreover, immediate financial needs such as repaying debt



from migration (i.e., pay the 'coyote' or smuggler) and sending remittances to family in their home county are argued to fuel excess injury because workers value short-term financial gain over the possibility of injury in the future (Flynn et al. 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011). Indeed, as Arcury and colleagues (2014) reported, "Mexican workers do not value safety or taking precautions" (p. 720).

Implicit in this small but growing body of research is the view that construction contractors or managers (e.g., "foremen") exploit these beliefs for personal gain. The frequently reported observation that work speed is more important than safety is often interpreted as the contractors requiring a faster pace of work (Arcury et al. 2014; Flynn et al. 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011) or indirectly incentivizing it through piece-rate compensation (Flynn, Eggerth, and Jacobson 2015). Similarly, immigrants' employment precarity owing to documentation status and financial need is typically interpreted as exploitative contractors who leverage workers' hardship to maximize their gain. Although this may be true in some situations, the more significant point is that the voices and perspectives of contractors or those who employ workers are missing.

The perspectives of both contractors and workers are sorely needed to develop strategies for eliminating occupational health disparities borne by Latino workers in the U.S. Nowhere is this need more salient than in the small-scale residential subsector of construction, described in the Overlapping Vulnerabilities report (NIOSH & ASSE, 2015) as having the most significant risk of occupational injury and fatality. This subsector has few, if any, supports for attending to occupational safety. The "contractors" are often working side-by-side with hired immigrant workers. Contractors are increasingly immigrants themselves with little or no training on "best practices" for their business or safety within that operation.

The overall goal of this study was to take a first step toward developing materials to reduce injury among immigrant Latino construction workers in the small-scale residential subsector of the industry. The specific aims were to describe attributions of common construction injuries by both workers and contractors and compare and contrast those attributions to identify points of synergy and divergence that can be leveraged for effective intervention.

METHOD & MATERIALS

Study Design

This research is part of *jPonte Listo!*, a sequential mixed-methods study of occupational safety among immigrant Latino workers in the small-scale segment of the residential construction industry in Tulsa county, OK, USA. The data for this analysis are from the qualitative component of the project, including the Latino construction workers and contractors.

Participant Recruitment

Recruitment was facilitated by the research teams' previously established relationships with organizations and agencies serving the immigrant Latino community. The inclusion criterion for construction workers was: (1) self-identify as Latino, (2) employed in the residential construction industry for at least one year, and (3) worked as a framer or roofer in residential construction for 20 hours or more in the past month. The inclusion criterion for contractors was: (1) owner of a construction establishment with fewer than nine workers for at least three years, (2) majority of revenues are from activity in residential construction, and (3) having had one or more immigrant Latino workers for a minimum continuous period of 6 months. All potential participants were referred to study staff by individuals in this network of community contacts and recruited by trained bi-lingual study staff.



Data Collection

An Institutional Review Board approved study procedures. Two trained interviewers collected data from December 2019 through February 2021. Interviews were conducted at locations of the participants' choosing, usually their homes. Before any data collection, participants were informed of the purpose of the research and reminded that participation was voluntary. Signed informed consent was obtained from all study participants. Data collection did span the COVID-19 pandemic, resulting in n=12 interviews (5 contractors, 7 workers) conducted in an in-person, face-to-face environment, and the remainder (n=9) were achieved through Zoom (4 contractors, 5 workers). Participants received a \$25 incentive at the end of the interview. Digitally recorded interviews ranged in length from approximately one to three hours.

Interview Content

The qualitative component's goal was to understand the knowledge and beliefs surrounding occupational safety and injury held by workers and their "employer," the contractors. The interview guides for each stakeholder group were distinct, but they shared a common set of content. All interviews began with basic information about the participant. Then the interview moved into questions to probe fundamental beliefs about hazards confronted by workers in small-scale residential construction and the perceived causes of common injuries experienced by construction workers, including falls from heights, strains, and injuries from equipment. A core component of these beliefs was whether injuries were controllable, and if so, who is responsible for avoiding hazards and injuries. Finally, all interview guides asked about barriers and facilitators for working safely.

Analysis

All interviews were digitally recorded. The interviews were transcribed verbatim in Spanish and then translated into English by a professional transcription service. All investigators reviewed each of these transcripts and determined that theoretical saturation was achieved. A coding dictionary was constructed based on a-priori content underlying the construction of the interview guide (e.g., controllability of injury, beliefs about safety) and new ideas that emerged from immersion into the data. Two team members independently coded each transcript. The majority of codes had excellent inter-rater reliability (Cohen's Kappa ranged from 0.8-1.0). Some of the codes had poorer inter-rater reliability, but coding agreement was achieved through discussion.

NVivo 12 (Version 12 QSR International Pty Ltd. NVivo qualitative data analysis software, 2018) was used for data management, coding, and to facilitate analysis. For the analysis described here, segments for three codes; those related to (1) perceived causes of injury (i.e., CAUSES), (2) worker behaviors that may contribute to injury (i.e., BEHAVIOR), and (3) descriptions of experienced or observed adverse events (i.e., ACCIDENTS) were culled from across all transcripts using an NVivo report and subsequently reviewed. Regular meetings were held at which the team identified themes and patterns in a particular code, related it to other codes, and constructed matrices of related ideas. Variations by contractors and workers were noted, and when appropriate, separate matrices were constructed.

RESULTS

Participant characteristics

This study included n=9 Latino small-scale residential construction contractors and n=12 immigrant Latino construction workers. All participants were Latino, male, and the majority of participants did not graduate from High School. Although we anticipated a combination of Latino and non-Latino, we could only locate and recruit Latino contractors in the community. The contractors ranged in age



from 29 to 46 years, had spent on average of 15.3 years in the U.S. and approximately 12.5 years working in construction. Workers ranged in age from 18 to 50 (M=31.2), had been in the U.S. for 10.5 years, and had performed construction work for an average of 8 years. Complete descriptive information for the sample is included in Table 1.

Every contractor and worker personally experienced harm while at work that was typically characterized as "nothing serious." Only a portion reported personally experiencing an "injury," which was characterized primarily by whether it resulted in the inability to continue working. About half of the contractors and a quarter of the workers experienced an injury that resulted in lost wages. By contrast, every contractor and nearly every worker knew of a construction worker who was injured on the job.

Contractors Perspectives on Injury

Analysis of the contractors' interviews yielded two primary themes as the significant causes of injury among immigrant Latinos in small-scale residential construction. The first theme, ***That's Just the Way We Are***, reflects what is believed to be a cultural view that safety is unimportant, especially compared to earning money as quickly as possible. For example, when asked, "in your opinion, what are the causes of injury in residential construction," C1 responded:

I think it's because we try to show bravery and because we don't wear the protective equipment. I believe most of the accidents could be prevented. I think avoiding accidents is in our hands. Sometimes, the equipment could fail, but most of the accidents could be prevented if we used the appropriate safety equipment.

And when pressed to determine if training about using protective equipment would help, the same contractor commented:

*No, I don't believe so. I think the problem is more a cultural one than anything else. People **don't want to be careful** (emphasis added) at work. Even though they will benefit, they know the job is dangerous. They don't see that wearing protective equipment helps them in case they have an accident. They don't want to use it because it's uncomfortable. They feel it hinders them at work. And since **we get paid** (emphasis added) according to what we do during the day, we don't use it.*

C1's point that "...people don't want to be careful..." reflects a dominant sentiment expressed by contractors. Indeed, nearly every contractor referenced "carelessness" or a related term (e.g., "not paying attention" or "distracted") as being the primary reason why Latino construction workers are injured in their work.

Underlying ***That's Just the Way We Are*** were three sub-themes that attribute a "cause" to the effect of not caring about safety or being "careless." The first sub-theme or cause of carelessness is Money Motivated. C1, quoted above, stated that comfort impeded his roofing workers' use of protective equipment. However, he also attributed it to workers' belief that protective equipment hindered their work, whether it is due to the time it takes to put it on, secure it, move it, etc., or the physical restraint it poses to movement. Because the workers are paid by the job, not by the hour, any time not committed to replacing the roof was lost money. Another contractor put it this way:

... they work by contract and want to finish it as quickly as possible. Another thing is that those [roofing] jobs are well-paid, and people want to make more money. ... Going back to talking about productivity, if you tie off or wear a harness, you won't produce the same amount because you have to be tying and untying anytime you move from one place to another. So, your production is reduced [and you make less money]. C6

Substance Use is the second subtheme underlying ***That's Just the Way We Are***. Although some contractors attributed workers' substance use to their age, essentially "what do you young,



unattached men do for fun – they party," others intimated that it was embedded in what it means to be Latino. Regardless of the source, substance use or its effects, was used to explain worker carelessness. For example, when asked, "what are the most common causes of injury in residential construction?" C4 responded,

Well, because people don't take precautions, because they work hungover, and because they drink on the job. ... [preventing injury requires] your five senses all the time ... If you're working in a dangerous place, you have to be focused all the time because you can step on a paper, a hose, or anything and slip. So, we need to be focused on what we're doing.

Finally, contractors consistently alluded to the idea, They Just Don't Listen, which is the third and final subtheme of ***That's Just the Way We Are***. Sometimes the contractors attributed this idea to youthful naivete, like Contractor #4 said, "as I told you, we think we're 'Superman.' We can fly". Others stated it plainly, "Another problem is that Latinos are very stubborn and want to do things their way. We want to do things the way we think is right" (C6).

The second central theme contributing to worker injury in residential construction was ***Insufficient or Inadequate Equipment***. Contractors, all of whom received subcontracts from more significant operations, often talked about not having sufficient equipment or materials for the job. For example, C2 commented,

We return to the same thing about the equipment. If a nail gun doesn't work right, you might think you nailed a piece of wood when, in reality, it didn't happen. Then, when you stop holding it, it will come loose and hit you. So, the equipment has a lot to do with that [injuries].

C2 went on to say,

Well, patrons [general contractors] have to be more aware of the situation. If they want the job done quickly, they have to provide all the necessary equipment. Also, we, as [sub] contractors, have to have all the materials and equipment ready before we start the job.

Workers Perspectives on Injury

Analyses of the workers' transcripts yielded three dominant themes underlying elevated injury among immigrant workers. The first theme, ***We are Careless***, reflects the idea that Latinos do not think about safety or the potential of injury when they work – they "just do it." Indeed, just about every worker used the term *descuidados*, which translates to "careless" or something similar when asked why injuries are common among immigrant Latino construction workers.

... But, as I told you earlier, they're very careless and don't pay attention to what they're doing. There are workers who, when they are putting down paper on the roof, don't realize they've reached the end of it and fall off. I don't know what they're thinking about. (W8)

Yes ... carelessness because, sometimes, they're working but are not concentrating on what they're doing. And when they try to walk, they slide and fall off. (W2)

Underlying ***We are Careless*** were two primary explanatory subthemes. The first explanatory subtheme, We Don't Think about Safety, was a clear contrast between perceptions of American workers' views on work and safety relative to those of Mexicans. W4, for example, contrasted working for an American versus a Mexican contractor, which in this case was his cousin.

I've worked with Americans, and the difference is enormous - in the way they protect us. As I told you, I worked with my cousin in framing. When we're building a frame, he uses a 2 x 6 to walk on. Once, when my cousin didn't have work, I worked for an American and set up my 2 x 6. When he saw that, he told me to stop working. Instead of using a 2 x 6, we used a plywood structure. So,



we were able to walk freely. And with my cousin, I couldn't take my eyes off my feet. So, there's the difference. Americans take more precautions.

The second subtheme, **Earning Money Comes First**, establishes the priorities held by Latino construction workers. This subtheme consists of two inter-related ideas. The first idea is working fast equals more money. Workers in the roofing and framing trades were typically not paid by the hour; therefore, in their minds, the quicker they completed one job and moved on to another, the more they could earn. W3 described it this way,

Another reason is because people don't get paid by the hour. We get paid by what we do during the day. Then, we work hard to do as much as we can during the day. That leads to carelessness. We want to make more money by running all the time. If people working in roofing were to get paid by the hour, there wouldn't be so many accidents because everybody would be more careful. If somebody told you to hurry up, you would say, "Why do I have to run? I'm working by the hour." The problem is that people are always running and rushing on the job.

The second inter-related idea is that Safety Slows you Down. This notion was particularly salient for workers in roofing when talking about why harnesses are not typically used.

... it hinders your mobility on the roof. It's very uncomfortable to work with that extra weight because it makes you get tired and exhausts you (W5).

The majority of subcontractors don't have safety equipment for the workers. Or they don't ask us to wear it because, sometimes, it hinders us and decreases production. (W1)

W1's comment foreshadows the second dominant theme presented by workers; Contractors Lack Necessary Equipment. Workers understood that they worked at the bottom of the proverbial food chain. They understood their "contractor" or "patron" – who typically worked side-by-side with the workers – typically received his work from a higher level general contractor or "patron," which often created a situation that no one knew the job until they arrived on the site.

The contractor subcontracts a job, and, sometimes, that subcontractor subcontracts with somebody else. So, since there is no control, the equipment that is used is not appropriate for the job. (W1)

Yes, there are people who build their tools [like ladders or scaffolds] according to their possibilities. Some patrons don't have the resources to contract a company to bring him a scaffold or some machinery. The amount of money they make is not enough to pay for such things. So, they use whatever is available to build what they need. And then, that faulty equipment breaks down, and that is when accidents happen. (W5)

The third and final theme, **We're Pressured to Produce**, reflects the view that workers attributed the need to work fast to the pressure placed on them by their patron. They understood their "patron" likely underbid another contractor to win a job, and in doing so, that meant that success was driven by volume production. W4 described it this way,

I've seen that Latino contractors take jobs for less money than Americans do. And since they're getting paid less, they have to work very fast to be able to earn money. On the other hand, Americans charge a higher price, and for that reason, they take their time to finish a job.

Similarly, another participant, who was interviewed as a "Contractor" because he managed a small framing crew for his brother-in-law who had a larger business, described how the pressure to produce resulted in a traumatic injury.

Participant: There are patrons who ask workers to do more work than necessary. Once, we were still working, and it was 11 p.m., and we were still building a floor in a town located about one



hour from LOCATION. So, we were all mad and rushing to finish and come home. A man was cutting wood and cut these fingers off.

Interviewer: His thumb and index fingers?

Participant: Yes, the saw cut off his thumb and index finger. And since I was in charge of the group, he came to me bleeding with his thumb cut off. And even though that accident happened, my brother-in-law, who was the contractor, got mad and wanted us to finish the job. I told him that I was not going to keep working. I was very scared. I even cut myself slightly because I was so scared. What I did was take a hammer and destroy the saw with it. Without the saw, we couldn't continue to work.

Similarities and Differences in Contractors and Workers Perspectives on Injury

Several similarities exist in Latino contractors' and workers' beliefs about construction-related injuries. Both contractors and workers believed that Latinos do not value safety, at least not to the same extent as Americans. Contractors' and workers' comments also conveyed similarities in the belief that earning money takes priority over safety and that safety is an impediment to efficient work and subsequent earnings. Contractors and workers also believed that injuries resulted from having inadequate or insufficient equipment on the job site.

However, there were also meaningful differences in how contractors and workers talked about similar ideas. Contractors seemed to attribute what they referred to as "carelessness" as a character flaw of workers that needed to be managed. C6, for example, put it this way,

They take unnecessary risks while they do the job. That's a situation where you have to battle with them (emphasis added). You tell them not to take those risks and to do things the right way, even if it takes longer. But they don't listen. For example, after you've had a safety meeting with them in the morning, later on, the job, you see them doing whatever they want, regardless of what you just told them. They're stubborn, and safety is not something important to them.

By contrast, while workers acknowledged being careless – primarily because they prioritized earning money over safety – they did not view carelessness as a problem. They understood that carelessness could lead to an injury, but their sentiments suggested that lack of training left workers unaware of risks or hazards. For example, W1 said, "...workers don't receive the training they should receive..." in response to a probe about why workers may not use equipment properly. Similarly, W3 commented, put it this way,

The patron says that you don't need to be trained in roofing because what training do you need to carry a bundle to the roof? Or to pick up trash? That's the reason that I say, in roofing, you're responsible for your own safety. But if there were some requirement that forced training, it would be different

Contractors, by contrast, placed the responsibility squarely on workers and argued that training was unnecessary. For example, when the interviewer was trying to summarize several points about the causes of "accidents," including the potential of training, C1 placed responsibility on workers' carelessness, saying:

You could train a person, but I think it's very difficult to try to think the way people think. Our mindset is if we work less, we're going to make less. And the equipment is going to hinder us from doing our jobs. For that reason, we don't use it.

Another contractor went so far as to suggest that training and attentiveness to safety can create the potential for injury.



I think training and safety are exaggerated. I think there are too many rules and requirements. Once, I worked in [LOCATION], and the rule there is to anchor off by using a harness. I remember there were six or seven of us. We were pulling off the old tiles - walking from one side to the other, and the ropes all started to get entangled. When I saw that, I said, "An accident is going to happen here because everybody is all entangled." A while later, one of the guys I was working with tripped and almost fell off. (C4)

A second noticeable difference was apparent in contractors' and workers' explanations for why working fast is typical. Both agreed that working fast lies in the desire to earn more money given the piece-rate compensation system. However, whereas some contractors flatly reject working fast as a potential cause for injury, workers frequently report feeling pressured by their patron to work faster. As outlined earlier, workers understood that their patron would deliberately under-bid to win a job, resulting in a focus on volume production to remain financially afloat. However, this reality reveals yet another similarity between workers and contractors – both prioritize earnings over safety.

DISCUSSION

A small but growing body of research has documented immigrant Latino construction workers' beliefs about injury (Arcury et al. 2014; Flynn et al. 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011). Research to date has not considered contractors' perspectives, especially contractors in the small-scale residential subsector of the industry. Recognizing that an increasing number of contractors in this subsector are Latino, the perspectives of both contractors and workers are essential for the design of effective interventions to reduce elevated injury and fatality (NIOSH & ASHE, 2015).

This study replicates and extends the findings of previous studies whose samples were not restricted to the small-scale residential construction subsector. Like others (Arcury et al.), it was clear that immigrant Latinos in residential construction see limited value in safety or taking precautions. Similarly, like others, we found that speed of work is viewed as being more important than safety (Arcury et al. 2014; Flynn et al. 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011) and that injuries result from inadequate or insufficient equipment (Menzel and Gutierrez 2010; Roelofs et al. 2011).

However, our results go beyond previous research in at least two critical ways by considering both contractors and workers. First, contractors' and workers' attributions about injury and the putative value for safety are very similar. The similarity among contractors and workers may not be surprising, in part because the contractors were also Latino. Indeed, even when contractors were critical of workers' carelessness, they typically used the collective pronoun of "we" in talking about workers, suggesting that contractors identified themselves with being construction workers.

Second, despite substantial similarities among contractors and workers, meaningful differences create a type of "He-Said, He-Said" type of situation. Importantly, and perhaps not surprisingly, there was clear evidence that the often-reported need to work fast (Arcury et al. 2014; Flynn et al. 2015; Menzel and Gutierrez 2010; Roelofs et al. 2011) was both self and contractor-imposed. Similarly, insufficient or inadequate equipment on the job site occurs but is driven at least in part by the thin potential profit margins available to these sub-, sub-, sub-contractors. Narrow margins, of course, do not authorize unsafe work practices, but it also diminishes stereotypes of contractors who exploit vulnerable workers who have few options.

Implications

The potential salience of the observed similarities for improving occupational health among construction workers in this subsector of the industry cannot be overstated. The *Overlapping Vulnerabilities* report (NIOSH and ASHE, 2015), for example, and some of the initiatives that follow



(Eggerth et al. 2018), assume that contractors – like medium and larger businesses – prioritize safety but may not have sufficient resources to enact safety procedures. The results of this study suggest that assumption is questionable. These data indicate that small-scale residential construction contractors, like their workers, place a premium on finishing jobs quickly as a matter of keeping their business going.

Therefore, interventions to enhance safety in small-scale residential construction must include a focus on the worker, but deliberate attention must be placed on contractors. Like workers, contractors must believe that safety matters to model and expect safe behavior from workers. Safety training that acknowledges and accommodates the thin margins any small business experiences would move safety from a theoretical possibility to a lived reality. Although harder to implement, professional standards wherein subcontracting always requires regular worker safety training and specific safety practices would also help. Injury in small-scale residential construction may also benefit from contractors receiving small-business consulting or support in everything from how to design successful bids to advance preparation for executing won jobs and handling payroll. Clarifying business development and sustainability plans may help reduce injury because contractors, like their workers, prioritize earning money. Finally, a small contractor equipment cooperative wherein commonly used but costly equipment can be borrowed or leased at modest expense may help ensure the right equipment on every job site, regardless of the scope of the job.

Conclusion

This study's findings suggest that an increasing number of Latino workers and contractors in the small-scale residential construction industry share highly similar beliefs about the causes of injury and the value of safe work practices. There is a collective view that Latino workers are careless about safety and that carelessness is exaggerated by strong incentives to make as much money as soon as possible. These beliefs have been well-documented among undocumented immigrants in other sectors, and they offer clear, albeit frustrating, insight into the patterns of injury and fatality reported in the Overlapping Vulnerabilities report. The results demonstrate an undeniable need to include both workers and small contractors in strategies to promote workplace safety in workers in this sector of the industry.

Table 1. Description of participating contractors and workers

# Interview	Age	Years in the U.S.	Gender	Marital Status	Years of Education	Years in Construction
Contractors						
C1	34	14	M	Married	High School	10
C2	29	10	M	Married	11th grade	9
C3	34	13	M	Married	High School	13
C4	31	19	M	Married	5th grade	11
C5	46	19	M	Married		18
C6		17	M	Married		17
C7	32	14	M	Married	9th grade	9
C8	39	15	M	Divorced	High School	10
C9	35	17	M	Married		17
Workers						
W1	37	19	M	Divorced	Middle school	18
W2	18	2	M	Single		1
W3	50	23	M	Married	3rd grade	15
W4	38	19	M	Married	8th grade	14
W5	25	5	M	Single	Universidad	5
W6	20	4	M	Single	9th grade	4



W7	31	15	M	Married	High School	15
W8	37	9	M	Separated	5th grade	4
W9	32	14	M	Married	9th grade	9
W10	34	1	M	Separated	12th grade	1
W11	28	6	M	Married	11th grade	6

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Conflicts of Interest

The authors have no conflicts of interest to report

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Leading safety culture from the top: A typology for top leadership safety commitment

Siphiwe Gogo, Innocent Musonda

University of Johannesburg, South Africa

Correspondence: imusonda@uj.ac.za

ABSTRACT

The debate on leadership in health and safety (H&S) has been on many scholars and industry participants; however, this is directed chiefly to middle management. Recent literature establishes a balanced matrix of hard and soft skills whilst anchored on the type of leadership style as a driver. The reliance on leadership type limits the effects of environmental elements on the top leaders and how these leaders apply their effort in H&S. This paper reflects on the limitations of literature on leadership commitment in the transformation of H&S culture and is directed to the construction industry in South Africa. The paper's contribution is on top leadership commitment aspects within the national setting. The study found that top leader's commitment incorporates cognitive and social intelligence and contextual H&S knowledge and discipline/science knowledge. It is found that these aspects are shaped by the national context and development approach on top leadership competency, specific to H&S. based on the findings, we propose a typology that recognises the effect of national context in the commitment required to make a sizeable impact in the transformation of H&S culture by the upper echelon leaders. The balanced-mix typology of hard and soft skills is developed from a literature synthesis through a systematic literature review focused on the top leadership commitment in the H&S context grounded on the contextual setting.

KEYWORDS: Construction, health and safety, culture, transformation, top leadership

INTRODUCTION

For many organisations in the South African construction industry, the critical question is to establish how a role improvement of top leadership will benefit H&S culture transformation (Fruhen, et al., 2016; Musonda, et al., 2018). Most literature, however, focuses on how H&S culture is linked to the leadership commitment, which is reflected in behaviour likely to result in favourable H&S outcomes (Biggs et al., 2008; Oah et al., 2018; Grill et al., 2019). Furthermore, it has been established that leadership serves as a critical antecedent to H&S outcomes (Musonda et al., 2018; Grill et al., 2019). Therefore, it is imperative to establish the basis for the antecedents to a formidable top leadership intervention that will impact an expedient H&S culture transformation.

Top leadership is described as a "neglected species" in H&S research (Reid, et al., 2008). Zuofa & Ochieng (2017) argue that top management's overwhelming minimalistic H&S participation leads to a marginal impact on H&S culture. Zaccaro & Horn (2003) noted that only 5% is aimed at the top leadership of all leadership literature. Likewise, top leadership's systemic and functional effort on H&S culture change are principles whose implementation in the construction industry has been inadequate. The construction industry lags other sectors, such as oil & gas, medical, food, technology and mining, despite increasing concern by stakeholders (Grill, et al., 2019). Moreover, the misconception is aggravated by the widespread attitude which encourages top leadership duties in a delegation hierarchy, limited to supervisors and lower managers (Ncube & Kanda, 2018).

Top leadership neglect of H&S as a critical organisational risk results in destructive outcomes, thus demonstrating that behaviours and actions that are inappropriate, inefficient, unsafe or lack of



commitment could result in accidents in the workplace (Xuesheng & Wenbiao, 2012; Doh & Quigley, 2014; Tetrick & Peiró, 2016; Emere et al., 2018). Over the years, multiple devastating H&S accidents were linked to inadequacies in leadership (Xuesheng & Wenbiao, 2012). Empirical evidence suggests that top leaders have deliberately neglected H&S or lacked the ability and commitment to direct H&S in the workplace (Akelsson et al., 2012; Xuesheng & Wenbiao, 2012). This is reinforced by Haupt & Smallwood (2007), who reported that about 34 per cent of top managers, compared to 18 per cent of site-level managers, had not undergone H&S training.

Hambrick & Mason (1984) maintains that top management defines the business's vision, outcomes, and strategic position. This perspective is reinforced by Peterson et al. (2003), whose theory on Top Management Team (TMT) is a five-factor model that examined the value-added personality qualities of the top leader. A proportion of H&S leadership models, such as the "LEAD (Leverage, Energise, Adapt, Defend) model" developed by Griffin & Talati (2014) and the "Frontline H&S Leadership Maturity Model" developed by Oswald & Lingard (2019), draw attention to leadership and constantly refer to top leadership commitment. Still, these models are targeted explicitly at middle and lower management who have less influence on culture.

Caldwell (2018) posits that culture should not be neglected while designing and implementing any strategic policy. Moreover, Reason (1998) argues that altering the values and behaviours of an individual by basic communication strategies are unlikely if demonstrable, normative actions and conduct informed by the directive of the organisations are not present.

The importance of top-down leadership in the development of H&S culture has been demonstrated in other industries by Fruhen et al. (2014), Fruhen et al. (2016) and Amedu & Dulewicz (2019). Perhaps, learning from this sector could be beneficial to construction.

The concept of leadership by Ayodele & Olubayo-Fatiregun (2010) focuses on a knowledge orientation aimed at middle and lower-level management and the implicit belief that upper executives are ideally fit to serve discipline-specific aspects of the industry, like H&S. That concept is firmly criticised by Zwell (2000), who supports the approach of developed rather than inherent competency in leaders. Crutchfield & Roughton (2014) offer an opposing position to the paradigm that defines top management as fundamentally capable by pointing to the observation that most upper-echelon leaders have only abstract and rather common views of the importance of H&S, thus supporting the claim by Zwell (2000).

Based on how leadership commitment can be conceptualised and operationalised by focusing on a leader-centric approach and further exploring the hard-skill approach, we propose a typology for top leadership H&S commitment, which explores the appropriate contextual knowledge base to impact H&S outcomes. This is accomplished by first providing a detailed summary of the principles of H&S leadership in construction, the value including both H&S accomplishment and overall business success. The gap established by the pervasive focus on leadership styles and ignorance of the contextual setting in previous literature served as an incentive for this study. The results presented by this paper provide a comprehensive argument into the barriers to enabling a positive H&S culture in the construction industry.

METHOD

Approach

The Systematic Literature Review (SLR), in which scanning of keywords from literature, coupled with the SALSA (Search, Appraisal, Synthesis and Analysis), were the empirical methods used to unravel themes and critical arguments on the subject (Samnani, et al., 2017). The literature review method would seek to identify essential evaluation and thorough study of a subject (Winchester & Salji, 2016). The study's main aim was to establish a framework by collecting and evaluating results from the search. Methods such as keyword quest, a categorical quest for segregation and distinct analysis were also implemented (Winchester & Salji, 2016).



Results

Thirteen of the 33 articles studied centred on styles of leadership. Even on the twelve articles that reflect on leadership styles, nine were often based on the assumption that top leadership commitment is founded in terms of leadership style. The following section outlines key themes arising from the critical review of the literature.

THEORY

Leadership type as a driver of culture transformation

Most contemporary leadership theories comprise transactional, transformational, servant, and visionary styles (Bass & Bass, 2009; Yahaya & Ebrahim, 2016). Recent research has suggested new types of leadership, like pragmatic, ideological, ethical, authentic, distributed, modes of public leadership, theological and integrative (Anderson & Sun, 2017). Several of the new models were argued to show similarity with traditional leadership types and one another, leading to the legitimacy of their novelty being questioned by several scholars (Ricard, et al., 2017). A transformational leadership philosophy is among the prominent ideologies underpinning leadership (Northouse, 2019). Fernández-Muñiz et al. (2014) and Mukwakungu et al. (2018) found transformational leadership to be a preferred style in encouraging H&S outcomes. Northouse (2019) notes the "contextual school of leadership" to be fitting the applicability in a contextual setting. This school is described as intricately linked to the philosophy of contingency leadership. Still, it is characterised by the capacity to interpret leadership in a setting of its integration, making it more flexible.

De Jager (2018) and Oah et al. (2018) suggested that H&S leadership can be a pivotal factor in reducing perceived risk among employees. Leadership styles have been viewed as tools to effect H&S improvement and culture; however, little is done to direct how critical elements can be developed in practice to establish the H&S-specific competency in top organisational leaders. This leads to the assumption that the practical methods provided by styles are homogenous and are dependent on the follower's perception of top leadership, culminating in the following proposition:

P1: *A set of critical, contextual top leadership elements are needed to impact H&S culture in the construction industry.*

Leadership commitment as a driver of culture transformation

Fruhen (2012) indicated that H&S awareness and social competency should guide top leadership direction and learning. Agnew & Fruhen (2019) centred on H&S culture and leadership and how these contribute to various specific H&S consequences in the workplace. H&S culture conceptual frameworks represent an organisation's core beliefs and principles on H&S (Clarke, 2019). Crutchfield & Roughton (2014) and Roughton et al. (2019) proposed that the way the organisation is driven and operated subsequently affects and forms the SMS. The view that H&S professionals have the duty of counselling senior leadership on SMS has indicated a noticeable shortage of H&S perspectives on top leaders (Martin & Lewis, 2014; Zuofa & Ochieng, 2017).

Imboden (2014) postulates three main aspects at the core of strong leaders: performance, corporate culture and development. Such functions are top leadership matters that should never be reassigned. Despite this, Skeepers & Mbohwa (2016) assert that there is a general belief that suitably qualified people should independently take H&S responsibility in their areas, referring to either H&S officers or managers as the responsible persons in charge of H&S in the workplace (Mashwama, Kale, & Aigbavboa, 2018). It can be assumed then that delegation subverts H&S involvement and contextual competency. Based on the above arguments, the following proposition is stated:

P2: *Top leadership commitment has an impact on culture transformation.*

Understanding the broader context is crucial to aligning the actions of the company with organisational priorities. Marle & Vidal (2016) argues that the project complexity perspective establishes that small contractors participating in large project settings are faced with unique complexities contrasted with participation in small projects. Likewise, agility is key to large



contractors operating in different-sized projects (CIDB, 2009).

Consequently, culture is a critical entity necessary to ensure a successful H&S system (Biggs, et al., 2008; Armstrong & Fukami, 2009; Effelsberg, et al., 2014; Skeepers & Mbohwa, 2016; Lusenga, 2017). Reason (1998) posits that "unsafe culture is more likely to be involved in the causation of organisational rather than individual accidents", thus incorporating the organisational perspective. The assumption that top leadership impact on H&S is dependent on the perceived status of H&S concerning other core TMT agenda functions culminates in the following proposition:

P3: *Top leadership H&S commitment has a direct positive influence on H&S culture outcomes.*

Cooper (2010), Yang et al. (2011), van Heerden et al. (2018), and Oah et al. (2018) emphasise the significance of organisational leaders in the improvement of H&S outcomes by aligning them to the requirements of increased participation in H&S matters. This means that the hands-on elements of top leadership commitment require technical and contextual H&S knowledge. Therefore, the following proposition is stated:

P4: *The hands-on, visibility-driven competency approach has a positive influence on H&S outcomes.*

Contextual competency as a driver of culture transformation

Katz (1974) identified three key competencies essential to leaders: intellectual, interpersonal and technological, then revised by Peterson & van Fleet (2004) to a nine-skill approach. Likewise, five criteria identified by Mumford et al. (2000) for successful leaders seem to be: proficiency, personal qualities, emphasis on knowledge, power and results. Fruhen (2012) clarified the top leadership position by hypothesising the six-element paradigm. This framework indicates temperament, problem-solving, legislative emphasis, awareness of health, social competency and leadership.

Top leadership commitment in an organisation's H&S initiative is expressed by the individual's initiatives to facilitate adopting a workplace H&S culture (Okorie, et al., 2014). The impact of the resultant culture is primarily determined by the mechanism adopted, the execution approach, the environmental and organisational background and, the degree of competence of all actors, including the relational competence of top management (Zwell, 2000; Biggs, et al., 2008; Maliwatu, 2018). Zwell (2000); Akelsson et al. (2012); Okorie et al. (2014), and Trivellas & Reklitis (2014) offer opposing competency requirements for top leadership, with regards to organisational culture and leadership in general, where their collective assertion emphasis is the importance of competency in the understanding, grouping and application of H&S leadership. Perhaps adopting a structured H&S competency development and evaluation tool such as the Systems Thinking Education Program (STEP) will benefit construction H&S transformation efforts. Therefore the following proposition is stated:

P5: *A structured H&S leadership framework will promote H&S positive outcomes.*

Zwell (2000) argues that although company owners prioritise particular skills for executives, managers and workers, they are not enough. The responsibility of establishing this community and maintaining its longevity depends on the business' CEO's capacity (Zwell, 2000; Trivellas & Reklitis, 2014). As a result, the following proposition is stated:

P6: *Reliance on soft skills negatively influences the value of contextual H&S competency in top leadership.*

Contextual setting as a driver of culture transformation

Maliwatu (2018) affirms that context brings significance and emphasises the organisations' inner and outer environment aspects. The world influences organisations they work in (Thompson & Bevan, 2013). Johnson et al. (2008) express that; such conditions may cause deterioration for the company and the setting in which companies conduct business.

A form of subjective and context-driven approach is suggested by Ditsele (2018) and is founded on

Pepper's (1942) systematised worldview, which is rooted in the assumption that for the construction sector, a particular leadership style H&S-relevant implementation should decide the form of leadership skills needed. This efficacy may perhaps be used as a model for a persuasive transformation of H&S culture in South African construction organisations (Smallwood & Snyman, 2017). Tear et al. (2018) and Grill et al. (2019) affirm the strong influence of a nation's cultural background, noting that. In contrast, a generalised stance to leadership in H&S in constructing the regional cultural environment ultimately influences an organisation's leadership behaviours and H&S performance. This leads to the following proposition:

P7: *National and industry context has a direct influence on top leadership H&S commitment.*

Top organisational leaders narrowly view H&S requirements as policy and legislative H&S compliance. A plethora of policies further exaggerates this confusion legislation and standards in the market (Lusenga, 2017; Smallwood & Ayessaki, Influencing Workers' Performance through Health and Safety Interventions, 2017; Mashwama, Kale, & Aigbavboa, 2018; Ncube & Kanda, 2018; Smallwood, Managing health & safety (h&s) during the six stages of projects to reduce risk, 2019). It becomes clear that small and medium construction contractors propagate the persistent reliance on statutory and client compliance in contrast to a top-down, deterministic H&S culture. Based on this, the following proposition is stated:

P8: *Reliance on statutory, client compliance and Safety Management Systems directly relates to the status of top leaders on H&S.*

DISCUSSION

Approach

Findings revealed that the position of top leadership was challenging and required greater comprehension to ensure a decrease in the rates of injury to the workers. The eight propositions and their sub-propositions aim to establish top leadership commitment as a central theme that feeds into the critical elements aimed at transforming H&S culture in organisations. The assertions of this paper illustrate the theoretical cohesion and construct conjecture centred on the reported literature.

Possible interactions between the propositions

Table 1 summarises the eight propositions and how they contribute to the four principles of leadership type, commitment, contextual competency and setting. In this typology, the H&S competency creation and audit framework contribute to top leadership engagement, and the external environment such as regional culture also contribute to top leadership engagement.

Table 1: Initial theory development typology characteristics

<i>Functional capacity measure (variables)</i>	<i>Functional rules of engagement</i>
<i>Leadership type/style</i>	Leadership type/style influences Contextual H&S competence training
<i>Contextual H&S competence</i>	Contextual H&S competence training alters Top leadership commitment
<i>Top leadership commitment</i>	Contextual H&S competence varies with Top leadership commitment
<i>National & industry context</i>	National & industry context influences Top leadership commitment
<i>Main (Transformation) element</i>	Top leadership commitment alter organisational Culture & H&S Culture
<i>Virtuous circle (reinforcement element)</i>	Contextual H&S competence training varies with the H&S outcomes resulting from the H&S Culture

For this typology, the contextualism approach to philosophy is reinforced by meaning overarching foundations. This background, which is the national culture and construction industry, constitutes the base where contextualism system as attaching components. This typology argues the assumption of related but more leader-centred models that overlooked aspects of contextualisation as the significant effect mostly on outcomes of how the leader would act. The suggested typology described in Table 1 shows that all competencies relate to the personal engagement of the top leadership. In contrast, the statement offered in this analysis is that all these factors result from how a larger



context where the leader operates has formed, acted, and is influenced.

Limitations of the propositions and future studies

This study focused on propositions developed from the literature review. Future studies are needed to examine the propositions empirically to establish their validity and relevance in this literature and the context of the South Africa construction industry.

CONCLUSION

Literature found that only three of the collected H&S leadership literature reports directly discussed top leadership regarding H&S culture development in construction organisations. Few studies have been undertaken in Denmark, Trinidad & Tobago and Nigeria. Before, little to no top-level H&S-specific analysis of this sort has been identified for the South African construction industry background.

The critical contribution of this paper is the establishment of eight propositions and respective arguments to answer the fundamental question of whether a position-enhancement of top leadership would help the transformation of H&S culture in the construction industry in South Africa. We propose a typology that recognises the effect of national context on top leadership's commitment required to impact H&S culture transformation.

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Safety Implications of Using UAVs in Construction: An Ethical Perspective

Mohammad Khalid, Mostafa Namian, Michael Behm

East Carolina University, USA

Correspondence: namianm19@ecu.edu

ABSTRACT

The applications of Unmanned Aerial Vehicles (UAVs), also known as drones, in construction have been rapidly escalating due to their prevalent advantages in accessibility, cost, and efficiency. As a result, over the last decade, many construction companies have utilized drones in their projects by curbing manual labor into technology-based automation in construction surveying, remote monitoring, progress tracking, surveillance, and inspection. Aside from the astonishing opportunities of UAVs, they can pose significant safety and privacy risks to workers. Construction is reported as one of the most hazard-prone and fatal industries. The predominant integration of drone operations brings in a wider spectrum of unwarranted risks and hazards. The safety implications of drones in construction have recently received much attention from researchers and practitioners. However, there is an evident scarcity pertaining to the underlying ethical challenges impacting the safety and wellbeing of the construction workforce. This research aims to review the existing scientific literature and government regulations in place to address the undesirable aspects of using drones in construction job sites from an ethical perspective. These ethical concerns pertaining to the utilization of drones can impede a worker's safety performance and jeopardize the physical and mental health of construction workers and expose them to vulnerable status. This eventually leads to compromised safety performance and hazardous situations. The findings of this study would help the construction professionals and practitioners who aim to safely utilize drones in their projects with the intention of keeping the workers' mental and physical health intact.

KEYWORDS: UAV, Drone, Construction Safety, Ethics, Risk.

INTRODUCTION

Unmanned Aerial Vehicles (UAVs) or drones are airborne systems that can be controlled remotely or autonomously using onboard sensors and computers. The ability to fly drones from a remote location or control station is enabled by the establishment of wireless networking links. Drones were introduced by the Department of Defense for tactical dominance on the battlefield. Soon they came creeping into the domestic lives of Americans when the authority started availing drones to curb illegal activities within the borders (Cracknell, 2017). Before long, drones were being used in all sorts of commercial and non-commercial endeavors. Even then, no proper set of guidelines had still been introduced in regard to its usage for domestic affairs.

Drones are a technological advancement that has stimulated the interest of a vast range of industries in recent years. UAVs have established an extended radius of proliferation within the construction industry. Many construction firms have already facilitated specialist drone services tailored to their specific production requirements. This sector saw an astonishing increase of 239% in drone technology integration in 2018 ("Drones in the Construction Industry," 2019). Owing to their certain benefits including low price and easy accessibility, professionals have leveraged and embraced the technology with immediate implementation on worksites with very little knowledge about the underlying safety implications. As a result, drones equipped with video cameras are commonly used as specialized construction equipment (Yi & Sutrisna, 2021). Drones are evolving as a modern form of autonomous



monitoring technology and reducing the need for human intervention. Research studies have been striving towards the implementation of drones to monitor site personnel. Drones' ability to collect large amounts of information and relay them in real-time makes them a powerful piece of advanced surveillance equipment. On the other hand, drones with onboard mounted cameras can raise reasonable suspicions and privacy concerns in most environments, whether they are public or private (Wang, Xia, Yao, & Huang, 2016).

Therefore, responsible usage of drone technologies has become a timely demand for strong consideration as drone integration increases every day. On the other side, the unfamiliarity and absence of comprehensive safety understanding open the door for cyber-criminals and other ill-intended groups to hack or even manipulate the functionality and capabilities of drones for malicious purposes (Yaacoub, Noura, Salman, & Chehab, 2020). UAV research in construction applications has mostly concentrated on the positive benefits and prospects of UAVs rather than the negative areas of impact such as privacy and associated safety concerns. UAV technology is fairly new in construction, and the full scope of the negative outcomes has yet to be addressed and further investigated. The threats could worsen if no regulatory plans are developed and actively implemented. From an ethical perspective, this article takes a standpoint to investigate the main ethical, privacy, and safety issues posed by the use of civilian drones in the construction industry.

RESEARCH METHODOLOGY

This paper is focused on a review of recent advancements in job site surveillance facilitated by drone technology. To establish the objective of this review paper, a holistic and systematic search method was adopted to find relevant literature from the Google Scholar database, American Society of Civil Engineers (ASCE) journals, and Elsevier journals, followed by a comprehensive review. The literature was located from the internet by using relevant keywords such as "UAV," "UAS," "Drone," "Construction Safety," "Ethics," and "Risk". Thirty-five articles and reports were identified which were later reviewed to extract information. This paper will present the collective information in a descriptive manner which would help to create a comprehensive understanding of the ethical issues pertaining to drone usage and their management tactics in a construction environment.

DISCUSSION

Background

Rapid Adoption of Drones

UAV applications have the potential to provide value-driven solutions for a wide range of applications that need a variety of capabilities. Recent technological developments in unmanned aerial vehicles have significantly aided in improving workplace safety conditions by reducing the requirements to deploy people in complex and dangerous work settings. Over the last decade, a handful of industries, as well as recreational or hobbyist groups, have adopted drones' productive applications, for various tasks ranging from detecting illegal migrants crossing borders to inspecting hazardous or contaminated facilities. With time, owing to the innovation of the latest technologies, drones are becoming cheaper and more accessible to a broader consumer base. Moreover, profit-seeking organizations are recognizing the advantages of UAVs by using them directly in industrial processes or merely by acquiring aerial photos for specialized objectives (Coelho, 2019).

Hazardous Construction Environment

The construction industry experiences a considerable amount of workplace fatalities and non-fatal injuries every year that need critical attention. Recently, in 2019, the United States' construction industry suffered a shocking number of occupational accidents (1,061) that resulted in fatalities ("Workplace Injury Statistics, 2020," 2021). According to the Occupational Safety and Health



Administration (OSHA), one out of every five worker deaths occurred in the construction industry (OSHA, 2020). One of the main causes of occupational injuries has been recognized as workers' unsafe behavior which primarily involves falls, struck by, electrocutions, and caught-in/between hazards. Along with rising workplace complexities and accidents, the construction industry has recently seen a remarkable increase in the number of drones used across several job sites (McCabe, Hamledari, Shahi, Zangeneh, & Azar, 2017). This elevates the complexity of construction sites to a significant degree, exposes workers to unprecedented safety hazards, and creates new safety and ethical concerns (Namian, Albert, & Feng, 2018).

Regulatory Roadmap

The roadmap of authorized usage of drones or UAVs in U.S. airspace was originally initiated by the U.S. Congress in February 2012 with the help of an act namely, the Federal Aviation Administration (FAA) Modernization and Reform Act. This aided the FAA in introducing commercial and recreational drone use in public. FAA currently regulates UAV utilization to ensure the safety of the general public. However, researchers have articulated the drawbacks of the FAA's small UAV rule (Part 107) to comprehensively address the safety concerns of drones. As commercial use in the construction industry like other industries is growing on a constant basis, construction becomes more vulnerable to drone-related safety risks. More comprehensive regulatory laws, safety rules, and operational strategies are required to address such emerging safety concerns.

Safety Risks of Drones

Drones are a relatively new addition to the construction industry, but they have gained mainstream recognition over the last decade. Practitioners have recognized and applied the advantages of this technology in real-world situations. However, it is important to notice that not everyone has a similar degree of understanding and involvement with drones on the same job site. For example, an engineer may be directly involved with the drone operation which is supported by his/her technical background and ability to comprehend the drone's certain actions. On the other hand, a general worker may only be familiar with seeing a drone being airborne without any detailed knowledge about how it operates and associated functionalities. This unfamiliarity may raise a degree of concern within the worker community while drones are operated around them and this may bring discomfort and anxiety in their working environment (Xu, Turkan, Karakhan, & Liu, 2020).

As of 2016, there have been no deaths as a result of drone-related collisions in the history of the U.S. (Calandrillo, Oh, & Webb, 2020). While civilian drone-induced accidents have not resulted in any fatalities in the construction industry, the safety implications presented by numerous studies are developed based on empirical data. However, no matter how nimble a small drone may look by its appearance, the drones can impose multiple layers of safety risks to the on-site construction personnel. Researchers have identified that drones on construction sites pose significant safety threats attributable to collisions with people and property, distraction, violation of privacy, or trespassing (Namian, Khalid, Wang, & Turkan, 2021). Also, research has shown how quickly drones are being introduced into the industry without appropriate safety and privacy management schemes to protect the employees from physical and mental damages (Khalid, Namian, & Massarra, 2021).

Research suggests that the psychological status of workers has influential effects on their behavior (Ahn et al., 2019). Moreover, the theoretical domain of behavioral psychology suggests that human behavior is mostly the exhibition of their psychological status (Ajzen, 1991). Therefore, if the psychological status is somehow threatened by the presence of any moderately familiar or unfamiliar technology on the job site (e.g., drones), workers may exhibit unsafe actions which may lead to dangerous outcomes (i.e., catastrophic accidents). In fact, unsafe behavior has been identified as one of the major causes of workplace accidents in construction (Yu, Guo, Ding, Li, & Skitmore, 2017). The introduction of UAVs to job sites can increase the risk of unsafe behavior due to privacy invasion



concerns among construction workers (Chang, Chundury, & Chetty, 2017). The dynamic nature of construction job sites is continuously adopting newer methods of refining production efficacy. Workers are often placed in situations where they are accustomed to working in one atmosphere and then have their environments suddenly changed or newer equipment is introduced the next day. The absence of a construction-specific safety manual for drones deployed on-site engaging with working personnel is the primary issue that requires immediate attention (Namian et al., 2021).

Personnel must cope with these types of complex environments on a regular basis on the job site. As a result, they must remain focused and maintain their safety performance tactics in terms of hazard recognition and safety risk perception. This allows workers to continuously scan the job site atmosphere and make prompt decisions depending on the situation (Namian et al., 2018). The readiness index has not been measured yet for the construction professionals in any specific way. However, researchers highlighted the current understanding of drone safety management in construction by analyzing existing research literature and government regulations (Khalid et al., 2021). On this note, the deployment of UAVs on construction can introduce a range of safety hazards that the construction industry is still unprepared for (Wang et al., 2016). Among these safety concerns, ethical issues have been generally overlooked despite their importance. The notion of ethical issues pertaining to drone operations can be linked to the ability to practice a professional code of conduct ensuring the preservation of privacy. The codes can control the usage of technology in a way that satisfies the privacy and safety obligations of the construction workforce. Without the existence of such systematic approaches on the job sites, it would be unethical and unsafe to fly drones over construction sites where construction workers are present.

Ethical Aspects of UAVs in Construction

The use of technology to monitor workers can potentially induce a sense of discomfort and distrust because of being constantly monitored and subject to performance evaluation all the time (Hovden, Albrechtsen, & Herrera, 2010). Drones are also major stimuli to distract workers (Namian et al., 2018). Therefore, workers' mentalities can be negatively affected due to ethical deficit in the safety management framework which can lead to dangerous outcomes on the job site. This leads to the possibility of harm that can be caused if there is no specific construction-based management framework that addresses the safety as well as ethical aspects of drones collecting personal information. In the following sections, the safety risks of drones from an ethical perspective are presented. The key privacy and safety issues are also summarized in Table 1.

Drones and Surveillance

As reassuring and secure as it might feel having drones flying around the worksite, nobody can bear the stress of being monitored all the time (Lidynia, Philipsen, & Ziefle, 2017). Figure 1 represents a group of workers being monitored by a drone. The feeling of being surveyed upon by the employers and contractors will only heighten the sense of alarm and nervousness, in turn, making it much more difficult for workers to perform at their normal productivity level and have the same safety performance. Flying drones can distract the on-site staff, collide with structures and objects, induce increased stress levels in the staff, which all highlight the matter of ethical accessibility.

Surveillance Insecurity

The usage of UAVs in construction sites to monitor on-site personnel for a better output is one of the ways these little gadgets are impeding the natural workflow of the workers. Without proper regulation of usage, the drones will continue to make work difficult to be carried out in a smooth manner due to being monitored all the time and collecting a vast amount of unnecessary information (Pauner, Kamara, & Viguri, 2015). As a result of ethical deficits, employees can develop a resistance to new technologies, resulting in a sense of lack of privacy, self-esteem, and certainty of their job position

(McAleenan, McAleenan, Ayers, Behm, & Beachem, 2018). Behavioral science research has addressed the importance of ethical issues in professional environments as a critical matter of concern (Kang, Price, Thorpe, & Edum-Fotwe, 2004). Workers can become nervous if ethical frameworks are not present or practiced on construction job sites which must be accountable to regulate the use of private information. Anxiety from blackmailing with confidential information or fear of an immigration crackdown and eventual deportation may increase the degree of stress among underprivileged employees and have a significant impact on their safe working performance (García, 2018). When the management introduces drones to monitor their activities and collect private information, the workers may feel more captivated leading to aggravated anxiety and severe nervous breakdown.



Figure 7: Construction workers being monitored by the drone.

Credit: [Emre Ucarer/Shutterstock.com](#)

Table 5: Summary of the key privacy and ethical safety issues

Issues	Summary	Sources
Drone Use	Drones are increasingly being used in construction. Construction workers are not widely familiar with drones and their associated safety issues are still being investigated. As a result, a clear understanding of the risks involved with drones in terms of safety, security, and privacy is not adequately implemented	(Khalid et al., 2021; Namian et al., 2021)
Privacy Risk	Drones with cameras can allow for continuous collection of workers' personal information such as location, activity, and work hours	(Pauner et al., 2015; Wang et al., 2016; Yi & Sutrisna, 2021)
Stress	Drones flying close to construction workers may cause stress or anxiety due to invasions of personal space and privacy	(Moud et al., 2019; Xu et al., 2020)
Ethics Deficit	There is no formal code of conduct ethically governing the collection and dissemination of the stored information	(McAleenan et al., 2018)
Cognitive and Mental Wellbeing	Issues such as fear of deportation for undocumented migrant workers and blackmailing by personal information to exploit into working more without appropriate compensation can impede workers mental wellbeing and overall safety performance leading to unsafe behavior	(Li & Liu, 2019; Lidynia et al., 2017; Martinez, Gheisari, & Alarcón, 2020)

Trespassing	Drones may be liable to trespassing and collection of private information if they accidentally gather details about their surroundings without authorization (Namian et al., 2021; Scharf, 2019)
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Workers Right to Privacy

According to the 12th article of the U.N. Declaration of Human Rights, “No one shall be subjected to arbitrary interference with his[/her] privacy, family, home or correspondence, nor to attacks upon his[/her] honor and reputation. Everyone has the right to the protection of the law against such interference or attacks.” Privacy is a basic human right, and the concept mostly makes people concerned when they are violated or threatened for exposure (Holmlund, 2017). This can be linked with drones collecting mass information from a project site and that being stored for strictly professional purposes. In that regard, the American Institute of Aeronautics and Astronautics recommended the FAA along with the end-users of drones to implement and adhere to a professional code of ethics while gathering classified material of the public (AIAA, 2013). However, infringement of privacy remains a major concern because existing common law does not guarantee either worker's or external individual's (proximity properties) right to privacy for exploitation triggered by modern drone technology (Scharf, 2019). Figure 2 depicts a drone surveillance image that records information about the target (workers) while also unintentionally gathering details about the surroundings and next-door neighbors.



Figure 8: Drone capturing information about the target as well as its surrounding properties.
Credit: [Christian Inga/Shutterstock.com](#)

Ethical Breach Affecting Safety Performance

Construction employees are often subjected to a variety of job-related hazards threatening their mental vulnerabilities especially if there is a shortage of suitable resources, manpower, and time. Many of these things will lead to severe stress and put them in unsafe conditions at work (Leung, Liang, & Olomolaiye, 2016). Jobsite personnel is constantly underpinned by the pressure of construction tasks which require their physiological and psychological efforts as well as unhindered cognitive abilities to assess the situation (Craik, 2014). Invasion of privacy or personal space can potentially be considered as a major issue that can startle most workers on the job and cause them to lose focus, leading to distraction and potential accidents (Moud et al., 2019). In fact, distraction has been found to be a major contributing cause of accidents in construction (Namian et al., 2018).



On the other hand, drones themselves have been identified as a major source of workplace distraction which is capable to seize the attention of the worker during an ongoing construction task (Li & Liu, 2019;). Another study has shown workers would stop their work and stare at the drone while it is hovering above the job site (Martinez et al., 2020). Distraction at the construction job can reduce the overall safety performance of the workers (Namian et al., 2018). The majority of distraction-related accidents occur as a result of failure to detect the possible threat of an incident before it occurs.

Influence of Cultural Background

A construction site is commonly occupied with people coming from diverse backgrounds and different levels of expertise. It is not also expected for them to have a comparable degree of experience with all the aspects of the job site. They receive various types of safety training, and the amount of transferable knowledge varies from person to person, which has a direct effect on their risk evaluation and safety outcomes. (Namian, Albert, Zuluaga, & Jaselskis, 2016). Researchers have also shown that workers and managers have significantly different perspectives on the effectiveness of the safety training they obtain (Namian, Kermanshachi, Khalid, & Al-Bayati, 2020). For example, Latin American workers comprise a large portion of the construction personnel. Accordingly, research shows that these community Latino migrants make up a higher percentage of workplace fatalities compared to the local or any other workers due to a range of factors such as education or illegal immigration status (Vazquez & Stalnaker, 2004). Moreover, fear of deportation prevents them from disclosing occupational accidents or injuries, dangerous working environments, and potential workplace hazards. Drones with cameras capturing their information may not be their preference while working on the sites. If they may believe their privacy is being violated, this may have a detrimental effect on their mental wellbeing and lead to unsafe behavior.

FUTURE RESEARCH

This paper reviews the existing literature and establishes a basis for further research on drone-related ethical and safety issues in construction. According to the discussion and the systematic review, drone-related ethical violations can have a negative impact on employees' mental health and can lead to dangerous conduct. Surveillance technologies are incredibly powerful, and they should be subject to regulations. Effective strategies must be developed to address such ethical concerns. The users should be open for accountability and the whole process should remain transparent. Laws should be passed limiting its power and codes of conduct be circulated for a peaceful and ethical usage of the device. At the company level, organization policies and ethical codes of conduct must be implemented to address the aforementioned concerns. The breadth of the literature suggested the basic challenges that would be tackled to ensure the safety and wellbeing of staff. Future studies should take these considerations into account in order to provide effective training and education materials. It is also advised that construction professionals be engaged in real-life experimentations in order to integrate validated results.

CONCLUSIONS

The positive shift in technological advancement is visible, and commercial industries are taking advantage of the opportunity to properly equip themselves with new devices. With the evolution of technology, surveillance has enveloped the entire world. Everybody has made peace with the fact that they are somewhat traceable. But having electronic surveillance devices hovering over our heads while we engage in regular activities will be, without a doubt, daunting. Psychologists say when people are being monitored, they tend to act differently and in particular behave unsafely. This paper attempted to close the gap between the limitless applications of drones and their safety constraints from an ethical perspective.



Drones are one of the integrations that are pushing construction job sites to the brink of maximizing production and efficiency while minimizing expenses and labor. However, when such sophisticated technology is introduced to a population of unfamiliar workers, it affects the aspects of health, safety, and privacy. Similarly, when such unmanned aerial vehicles will be introduced in a construction site to monitor the staff, it will have the potential to both distract and disturb workers and construction activities. The majority of workers will take quite a while to get used to the gadget and even after the initial phase, there will be the fear of the workers becoming less efficient due to the level of stress and nervousness it will impose. Drones may cause on-site personnel to become concerned and compel them to take acts that they may not have done in normal circumstances. The extent of variance experienced by someone as a result of their fear of drone surveillance may place them in a position where they are less worried about their safety and wellbeing. Future research must be conducted to provide effective strategies such as relevant training programs and educational materials to address such safety-related concerns of using drones in construction.

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CREATING GAME-BASED DRONE FOR IMPROVING CONSTRUCTION SITE SAFETY

Kenneth Lawani, Billy Hare, Iain Cameron, Hamid Homatash, Julie Campbell

Glasgow Caledonian University, UK

Correspondence: Kenneth.Lawani@gcu.ac.uk

Abstract

Technological advances in the construction sector promises faster and more streamlined working practices. Forward-thinking contractors are investing in digitizing their operations and the use of drones with the capability of providing real-time site information is already a reality. Deploying drones for site inspections can help construction and safety managers avoid placing workers in precarious situations and the ability to quickly gather site aerial data can be invaluable. This study focuses on creating a drone flying game for inspecting construction sites and identifying potential safety hazards. The single-player, user-focused game comprises of fun flying mechanics to control the drone and this is an integral part of enabling users to gain the experience of simulated flying of a real drone. The game platform is the WebGL for rendering interactive 3D graphics within any compatible web browser without the use of plug-ins. The target audience for user experience and usability testing are construction and safety managers, construction professionals and students working in the industry. Preliminary findings revealed that the drone game was fun to play; the game was intuitive and easy to pilot the drone; the hazards in the simulated construction environment looked real; and the game satisfies the main aim of the playtest. The skills acquired from playing the educational drone game for site inspection and monitoring can successfully be applied when flying a real drone in a construction site. The significance of using drones for site inspection during Covid-19 pandemic where workers need to be physically distanced is timely and relevant.

Keywords: Drone, Site inspection, Simulation, Game-based, Site safety, Web Graphics Library

Context

The adoption and use of innovative technology to improve construction operations, most significantly health and safety is becoming a norm as it is less expensive and more reliable than before. The use of drone technology in the construction industry has substantial potential in terms of improving safety inspections and construction practices (Xiang et al., 2018; Homann & McAllister, 2018). Workers within the industry are susceptible to accidents which could either be fatal or lead to permanent disablement as the HSE construction statistics in Great Britain for 2020 identified (HSE, 2020). The construction industry plays a significant role in economic growth in all countries. However, workers employed in this industry experience a disproportionately high rate of injuries and fatalities; for example, the UK (United Kingdom) recorded 40 fatal injuries to workers in 2019/2020 and this is consistent with the annual average over the last 5 years (HSE, 2020).

Construction companies promote the zero-accidents mantra, but this cannot be solely achieved with over-reliance on manual and random on-site inspections. The adoption of technology could serve as an intervention strategy with the capability of providing real-time information and feedback for construction managers, safety managers and workers. This becomes even more important when work on site is currently being conducted using a phased approach due to the global Covid-19 pandemic.



The Health and Safety at Work Act 1974 stipulates that all workers have a right to work in places where risks to their health and safety are properly controlled and safety managers have a responsibility to ensure that this goal is achieved. The idea of inspection or monitoring has been described by Toole (2002) as the frequent walk around the site to acquire real-time information through direct observation and interface with workers. Depending on the complexity of the site and the project, site inspection could become a time-consuming exercise for the safety manager. It can also become irregular with a failure to establish standard controls, get real-time data and provide requisite feedback because Occupational Safety and Health (OSH) personnel are required to carry out audits and inspections (Cameron et al., 2007). Therefore, the strategy to create game-based drone for improving construction site safety is to use technology to ease inspection of site safety issues, provide real-time feedback and improve safety management (Hallowell et al. 2010). The use of drone technology is considered a useful tool due to its capability to fly over difficult to reach and highly dangerous locations by ensuring that workers are safe; there is improved and streamlined time to conduct site inspections; and improved audit trail, see (Irizarry et al., 2012).

Furthermore, the construction market is seeing extensive use of drones on projects. The purpose of the game-based drone is to provide safety managers with the capability of learning how to fly a drone on a simulated construction site before undertaking the training towards acquiring the remote pilot drone licence with the UK Civil Aviation Authority (CAA). Therefore, playing the game allows the safety managers to experience the speed at which inspections can be undertaken and the accuracy and level of detail that can be acquired; the ability of the drones to reach inaccessible areas of the construction site, and the capability to transfer real-time information. The cornerstone of adequately implementing a good safety initiative is fundamentally reliant on how the construction and safety manager are able to plan, manage, monitor and control their work area which is why the adoption of the drone technology becomes important. The aim of this study is to explore the development of a drone game as a method for engaging construction managers and safety practitioners to adopt drone technology for site monitoring and inspections.

Use of drones - Drones or unmanned aerial vehicles (UAVs) is a technology that can be deployed in the construction industry for site inspection purposes. The current issues around limiting the number of workers on a construction site due to the Covid-19 pandemic (social/physical distancing) have consequences on the ability of safety managers to successfully undertake their site inspection responsibilities, most especially on complex or mega project sites. Technically, site inspection or walk around in itself can be maximised with the adoption of emerging technology like drones that are capable of undertaking site operational inspections in the unstructured construction environment (Zhou et al., 2018). Drones are normally operated under remote/autonomous controls without any on-board pilot. That means, the operation relies mostly on human involvement and the acquisition of drone flying skills, knowledge and experience. The deployment of drones for safety inspection purposes (Tantum & Liu, 2017), with the capability of providing real-time video of the ongoing construction activities cannot be ignored. The adoption of this technology as an add-on suggests that safety managers could potentially be able to provide immediate feedback and communicate with the workers in real-time, whilst not relinquishing their key responsibilities.

Within the UK construction industry, the most common causes of fatal injuries and the kinds of accident in the top five based on RIDDOR 2019/20 are – falls from height; trapped by something collapsing/overturning; struck by moving, including flying object; struck by moving vehicle; and contact with electricity (HSE, 2020). The rate of fatal injuries in the UK construction sector has not changed significantly over the last five years based on HSE statistics for the entire annual fatalities in the construction industry (HSE, 2020). The misunderstanding of the inherent risks associated with



working in the construction industry can be linked to inadequate supervision and failures by management to adequately address the unacceptably high rate of accidents (Gheisari & Esmaeili, 2019; Lawani et al., 2019). This could be due to the fixation in correcting the immediate causes or symptoms without addressing the root causes that could have been captured during routine audits, supervision, monitoring, or inspection. Therefore, the development of automated methods useful in identifying and monitoring hazards on a construction site can go a long way towards mitigating these types of accidents that workers can be exposed to (Fullerton et al., 2009). The development of the drone game is to serve as an educational resource to raise the level of awareness, improve the adoption of the drone technology and to significantly increase the skills and competence of potential drone pilots towards successfully flying a real drone or gaining the pilot licence. The essence of the drone game is for players to be able to deploy the drone on construction projects for site monitoring (Wen and Kang, 2014), inspection of building façades (Roca et al., 2013), safety inspection (Irizarry et al., 2012), ability to survey sites and projects (Siebert and Teizer, 2014), and construction progress monitoring (Han et al., 2015) without the personnel physically interacting with any of the dangerous activities on site. Other important elements of using drones are the low cost of acquiring a drone, the speed at which information can be gathered, the high level of safety associated with data gathering and the manoeuvrability of the drones (Siebert and Teizer 2014).

Safety Management & Real-time information - Drones have the capability to collect real-time data on the safety features or hazardous situations on a construction site. In one example, a major contractor in South Florida deployed drones towards improving safety performance and designers could virtually meet to review real-time situations and make changes before construction began (Goodman 2017). Therefore, the adoption of the drone technology as an intermediary tool for remote site inspections and real-time feedback is an added advantage with features such as the ability to capture images and site videos, useful knowledge for decision-making, and site safety planning.

Construction Monitoring & Inspection - Rather than having the construction or safety manager conducting site inspections on foot; a fully trained drone pilot has the capability to safely operate the drone by collecting real-time site information whilst reducing the risk to every worker on site (Irizarry et al., 2012). It is understandable that the manual process of monitoring and inspection of motorways, bridges, wind turbines, building cladding systems, roofs, and façade systems can be time-consuming and ineffective most especially when managing complex mega projects (Osunsanmi et al., 2020; Macrina et al., 2020). Therefore, deploying drones for monitoring and inspection purposes can improve site safety (Li & Liu, 2019) while also effectively monitoring the different phases of construction project. The ability of the construction or safety managers to have a bird's-eye view of the construction site can provide accurate and up-to-date information of the site which helps in making more informed decisions about any ongoing work.

Ethical Issues – The use of drones has its own ethical dilemma. As the use increases on site, workers and the general public become more concerned about their rights to privacy and data protection (Agapiou, 2020). Many workers perceive that deploying drones on a construction site is not all about improving site safety and security but another way for the employer to utilise the drones to invade their private lives or work (Irizarry & Costa, 2016; Agapiou, 2020). The height at which drones are flown is another issue of utmost importance to worker and the general public. The UK Civil Aviation Authority places the legal height limit of 120m (400ft) for flying a drone to reduce the risk of coming across other aircraft e.g. air ambulances and police helicopters that may fly below this limit. Also, the CAA advises that drone pilots must keep a minimum horizontal distance of 50m between the drone and people, buildings and transport and to keep at least 150m away from residential, recreational, commercial and industrial areas. This raises safety concerns for tall structures, such as cranes and the



safety of workers and the public during close inspections of structures or facilities of interest on site (Finn and Wright 2012). Therefore, this educational drone game is an opportunity for potential drone pilots to learn how to navigate and mitigate the consequences of any type of real drone failure, misuse, and operator error that could result in physical injuries before they embark on flying an actual drone.

Rationale for game design/Methods

The rationale for gamification in the context of this paper is to assess if this novel approach helps to introduce the concept of drone technology in an engaging and inexpensive way so that those managing, monitoring and inspecting site safety adopt the physical technology (the actual drones) quicker and more efficiently.

User experience - The user experience focused on how the player's experience can be improved and how players interacted with the game, such as navigation, ergonomics, and usability when playing the game (Irizarry et al., 2012). The user participation evaluation was performed following a simulated task. The player was required to fly the drone over the site as a form of inspection and spot specific number of hazards (six) within the construction site without crashing into any structure or the workers.

Usability testing - Systems have traditionally been designed and developed through a technology-centred perspective (Endsley et al. 2003). In such a perspective, the designers would accept the technology as it is and replicate same technology in different domains without ultimately considering the very important element - the end-user (human). In a technology-centred perspective, the end user and all its requirements are considered as identical even in different domains. For this study, a user-centred approach was employed. Unlike the technology-centred approach, the very first issue that this study resolved in a user-centred perspective was to ensure that the technology is usable - considering the real users' experience and their own requirements in a specific domain (Irizarry et al., 2012; Gheisari & Esmaeili, 2019). That means easy set of controls that are intuitive i.e. easy to figure out how to play the game and improve, cognitive affordance, visual language and accessibility towards reaching a wider audience. This user-centred usability-based step provided a grounded base for understanding the requirements for practical application of the drone technology in a domain. Developing the drone game technology seemed very useful for safety inspection practices. The main issue that needed to be resolved was whether this technology was usable for both construction and safety managers and construction workers. A usable system should be easy to use and learn to work with the least number of design errors by always keeping the game state clear and comprehensible.

User-focused perspective/User experience - A user-centred approach was employed in the development of this game following standard practices employed within the games industry (Irizarry et al., 2012; Gheisari & Esmaeili, 2019), by providing satisfying feedback in every actions through animations, sound effects, camera behaviour and animated post-process. The design team also ensured that added elements like the visual effects, art, level of design and audio increases the level of satisfaction provided by the game mechanics. This meant that user stories were created for the intended target audience and their relative experience with games in general. Since this project is focused on educating construction workers who may not be adept with playing computer games, the game had to be designed with the specific user in mind; using the on-boarding tutorial as a way of introducing players into the game and the mechanics and goal of the game. Therefore, the game had to be simple to operate, easy to access and intuitive to use. Early design decisions were made for the game to run in a browser using WebGL (Web Graphics Library) to facilitate easy access for players. Furthermore, the decision to use the WebGL was founded on the premise that most people would

have probably played some form of browser-based games and therefore, more likely to understand how to operate a game in their browser or at the very least, be comfortable with using a browser. That meant by using WebGL, the drone game is capable to run on mobiles, thus making accessibility and game play readily available to anyone.

To ensure the drone game was easy to play, accessibility was a fundamental priority throughout the development, and this was not just limited to the technology of choice for this project. User stories were created based on the target audience to gather the requirements for this project. This led to several prototypes of small portions of the game which were tested internally to ensure that the ideas in the user stories were appropriate, meaningful, fulfils the goal of the game and fit with the game design intentions. Several ideas were discarded during design but those that seemed plausible were collated and expanded before being documented in the form of a game design document. This outlined the key features the game must have to be successful from the perspective of users and what the current designs were that would achieve these goals. The main features identified were:

- The piloting of the drone had to be simple, feel intuitive and enjoyable to fly.
- The interface that users would play through should be simple and easy to understand even with no prior knowledge of playing games.
- The construction site itself had to feel animated, busy and realistic enough to feel believable.
- The hazards had to be as realistic as in a real construction site but also visible enough to be able to identify them, otherwise users will not learn anything or enjoy the experience.
- For users to retain the knowledge and make the experience more impactful, simple minigames with emphasis on construction hazards was introduced (Figure 1). This is important in showcasing the significance of finding the hazards which in turn would show why using a drone is safe and beneficial to undertake this type of site inspections.

The steps above outline the preproduction process of the game with emphasis on gathering analysis requirements for the drone game. It involved deducing the key features and requirements by the stakeholders and it was also essential that a vertical slice – a prototype of the game was produced to ensure the idea itself was viable. After showcasing the vertical slice to multiple stakeholders, it was evident that the overall idea of the drone game as an educational resource was practicable and could proceed into full production with the general design needing some iteration.

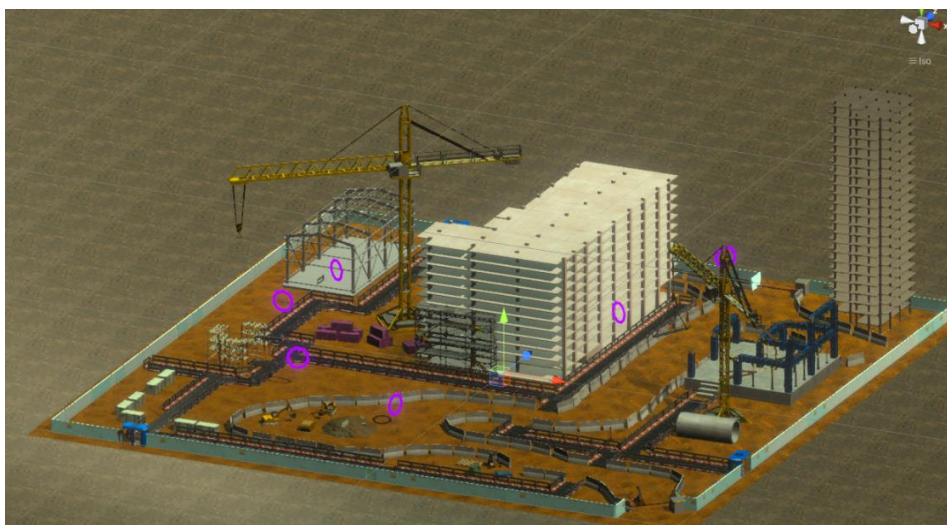


Figure 1: The hazard minigame

Findings and Discussions

Cognitive design - During full production of the game, it was crucial to ensure that the cognitive design of the game (functional and emotional expectations) aligned with that of the target audience. The principle of the game was not only to teach users about the benefits of drone usage on a construction site and the practicality of spotting hazards, but to be an enjoyable experience and an educational resource that will motivate users to interact and engage more with the simulation. Users that enjoy interacting with a game or find it fun are more likely to retain information (Przybylski et al., 2010). The focus of the game was to teach the basic skills of piloting a drone, how to safely operate a drone, and how to use a drone to spot or identify hazards so that users can visualise the benefits that drones offer on a construction site. To do this convincingly meant making the game feel natural, easy to learn and use without complex interfaces, engaging, and very realistic which was a difficult challenge. Striking a balance between all these features which can sometimes compete with one another is always an issue when designing an educational game. To resolve these challenges, the development of the game meant adequately addressing the following questions during the design:

- Does this scenario happen in a real construction site?
- Is this design easy to use or recognise for someone that does not play games?
- Does this feel exciting or enjoyable to play?

By reviewing every aspect of the game design using these queries resulted in several design and development issues being averted. For example, the flying of the drone itself needed to feel realistic and with the use of simplified controls to avoid overloading the cognitive abilities of the user. The drone also had to be practicable in terms of its size and starting position in the virtual construction site so that users would be fully immersed in the simulation. Most importantly, the drone game needed to have elements of fun and enjoyable experience to pilot, and designed to be practical and realistic. In the absence of the fun elements, users will be reluctant to play the game and most likely not comprehend the significance of using a drone for construction site inspection. Therefore, designing the drone by incorporating the fun features with simplified controls to lower the cognitive load was a challenge. The use of controls that are too simplistic will diminish the believability of the simulation, while making the controls real and complex means players would take longer time to understand how to operate the drone and hence, the user experience will be less fun learning the game. Therefore, the design and development needed to strike a balance between believability and realism, and enjoyment and ease of use.

Usability testing / Playtesting - Usability testing is essential to ensure a product is useable. However, game design goes a step further with playtesting which considers the user experience not just from a user interaction-based approach but also their cognition, emotion, and enjoyment (Pagulayan et al, 2018). This can be very subjective as people's cognition, emotions and what they enjoy can differ greatly. Therefore, playtesting is an extremely important lifecycle of developing a game. By playtesting multiple times both internally (within the development team) and externally (preliminary testing with the intended target audience), the team was confident that the developed game was on track towards achieving the objectives of the product, i.e. functional, usable, and reliable. The team regularly tested the game internally every week by gathering informal feedback on improvements. The internal testing helped to ensure that the overall design of the game and the way it interacts feels credible, indicating that the game was practicable with a high degree of confidence. To validate that the game was enjoyable whilst teaching the player about the use of drones for construction site inspection and hazard identification, the first preliminary external pilot playtest was conducted with seven participants. The seven participants for the preliminary testing session were construction managers with requisite knowledge of construction site health and safety challenges. They also had some



experiences of playing games and therefore could validate if the game was enjoyable and realistic which was the core objective of the playtest i.e. testing both the objective (usability, reliability and functionality) and subjective (convenience, enjoyable, engaging) characteristics. The data collection adopted the Likert-scale approach to scaling responses in survey research, through the Google Forms questionnaire, see Table 1.

The results from the preliminary testing indicated that the drone game was fun to play and enjoyable. The participants understood the benefits of using the drone for construction site inspection most especially during this period of Covid-19 pandemic where workers need to be physically distanced, work packages have to be sequenced, and with restrictions on the number of workers that can be present on site. Most participants indicated that the game was intuitive and easy to pilot the drone, and found the hazards in the simulated construction environment real, which satisfies one of the main aims of the playtest.

Table 1: Playtest Questionnaire extract

Question	Participants						
	P1	P2	P3	P4	P5	P6	P7
How fun did you find the game overall?	Very fun	Very fun	Fun	Mostly fun	Very fun	Very fun	Very fun
How well do you understand the benefits of using drones on a construction site?	Mostly understand	Fully understand	Mostly understand	Fully understand	Fully understand	Fully understand	Fully understand
How intuitive did you find the flight controls?	Very Intuitive	Very Intuitive	Mostly Intuitive	Not very Intuitive	Not very Intuitive	Mostly Intuitive	Mostly Intuitive
How useful did you find the compass for locating hazards?	Very useful	Mostly useful	Very useful	Not useful	Mostly useful	Very useful	Mostly useful
How realistic did the construction site feel?	Very realistic	Very realistic	Fairly realistic	Mostly realistic	Very realistic	Fairly realistic	Very realistic
Did you find the worker/vehicle paths realistic?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What did you particularly enjoy?	Complimentary messages when you identify a hazard	Flying around the site	The graphic seemed good and controls seemed easy	The entire game experience	Flying around the site	The controls and able to fly the drone	Piloting a drone
Any additional comments?	Great game, I liked it.	Really enjoyed it	None	None	None	Great idea, just a few tweaks and It will be a great wee game	Very enjoyable

However, there were some issues that needed to be addressed, e.g. element of the user interface was a bit confusing like the signal metre that displays the range the drone could fly before losing signal. Most of the participants identified that the in-built compass (Figure 2) for identifying and zooming into a hazard was useful in easily capturing hazards on site. Furthermore, the hazard minigames (Figure 1) although fun, some participants struggled to complete them or know precisely what they were required to do. Based on the feedback which indicated that the game has been a success, further refinements and other minor improvements were incorporated into the final version of the game e.g.

clear designated pedestrian access routes and vehicular routes (Figure 3). These external playtests have proven to be very useful as the team improved these elements and, in some cases, redesigned them. For example, the signal meter graphics was redesigned to be more similar to a wireless signal meter and this aesthetic carried through a revamped Heads-Up Display (HUD) from the perspective of the drone's viewpoint. Improvements to the keys used for the controls were introduced along with an alternative set that suited non-game players. The hazard minigames were also improved by using better in-game communication and instructions for what the user had to do and making the hazards look more obvious. Significant playtesting of the drone game will be further conducted with larger target audience (safety managers/inspectors, construction managers/supervisor) to ensure that the game is appropriate to the target audience and without ambiguity. The drone game inspection can serve as an educational training tool before undertaking the formal test for the Remote Pilot Drone Licence issued by the UK Civil Aviation Authority International (UK CAA). This will benefit the players in understanding how the use of drones can improve site safety, increase accuracy in identifying unsafe conditions, improve consistency of reporting, improve safety conditions through real-time spotting of hazards, and improve efficiency of site operations.



Figure 2: Drone game compass for locating hazards



Figure 3: Drone game inspection of pedestrian access routes

Conclusions

The drone game for site safety inspection reinforces the interactions between the players and the systems through the sensations and emotions provided by the gameplay. The minigame was another



way of introducing players into the goal of the game and its story to improve first-time user experience. The play testing and user testing of the drone game shows that the use of drones for safety inspections could be extremely beneficial in improving construction site safety. Although the use of drones can simplify safety inspections, it however takes away the human interaction associated with site walk around by the construction or safety managers, thus having a direct impact on workforce engagement. Also, there are ethical challenges regarding the deployment of technology on construction sites regarding privacy of workers and issues of data protection and usage. The use of drones in a complex site could potentially increase efficiency as the data captured can provide real-time information of the site conditions while autonomously inspecting the site very quickly. The adoption of drone technology for construction site inspections have the potential to also improve quality control in terms of using the drone to monitor design specifications during the construction phase of a project. The cognitive skills acquired from playing the educational drone game for site inspection and monitoring can be successfully applied when flying a real drone for monitoring or inspecting a multipurpose or complex construction site. The game offers the player a realistic level of understanding of the mechanics of flying a drone on site. The game creates high level of awareness, confidence and improved skill that can augment the skill required to secure the Remote Pilot Drone Licence issued by the UK CAA. The biggest challenge however was designing the game for specific audience that are probably non-game players so that the game is easy to learn, engaging, intuitive, and truly immersive.

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The Community Logic as a Springing Board of Innovation in Major Projects and the Role of OHS in Fostering It

Andrea Yunyan Jia

Graduate School of Higher Education, University of Melbourne, VIC 3010, Australia

Correspondence: andreayunyanjia@gmail.com

Abstract

Occupational health and safety (OHS) management in major construction project organisations has been practiced in two distinctive institutional logics: one is a protection logic upheld by the regulator and the union focusing on risk avoidance, another is a production logic upheld by construction people focusing on efficient delivery of the project. These two logics compete for resources and attentions in the project process, leading to suboptimal outcome in safety and productivity. This paper discusses the concept of a third logic that helps reconcile the two conflicting logics, the community logic, and its function as a springboard for innovation, as well as the role of OHS practices in fostering it. The research took a grounded theory approach. Three cases from on-site ethnographic fieldwork are illustrated to initiate a journey of theoretical development. This is followed by an iterative literature review between empirical and theoretical references. The results suggest that the community logic generates innovation by allowing the holistic person to function and take initiative, bringing in diversity, self-initiative, social capital and peripheral communication into the major project field. It focuses on building trust and partnership among the stakeholders to effect a secure environment that nurtures a supportive network in which actors can engage in open exchange of ideas for identifying needs and framing problems, from which innovation emerges. Extended OHS or CSR activities help foster a community logic by engaging diverse actors and giving lay users opportunities of participation in the project process. A path model is synthesized from the findings and illustrated as a recommendation.

Key words : Institutional logics, community logic, employee-driven innovation, health and safety, peripheral communication

INTRODUCTION

Safety and health in construction projects involves three major actors: the regulator, the project organization, and the workers' union. The regulator is concerned with employers' compliance on work health and safety regulations. The project organization carries the employers' duty of care to provide a safe work environment to its employees, but its primary interest in the project enterprise is business success and efficient delivery of the project for the client. The union's interest in health and safety in major projects is membership subscriptions and political popularity through visible actions of protecting the interest and welfare of their members, though often members' financial interest is weighed more important than their health and safety. The three actors are not only of different interests in the same issue, but their attentions and practices are underpinned and directed by different institutional logics. In Friedland and Alford's (1991) terminologies, we can see the regulator practices a state bureaucracy logic, which is rational control of human activity. The project organization practices a capitalist market logic, which is commodification of goods and services including safety. The union practices a democracy logic, which is to limit the power of the employers in the case of major projects. The three actors in their incompatible logics in the field of major projects



have different missions on safety, such that one party's efforts of improving safety are often contested or dissolved by another party's efforts of improving safety. For example, project organizations, in order to improve their safety and health management, try to first of all quarantine the union representatives in their origination to ensure the production work is not blocked for union-detected safety issues and on this basis, the project-based staff work hard to improve safety. Inside the project organization, there are two struggling logics between a production logic, enacted by the project organisation who are focused on 'time, cost and quality', and a protection logic, enacted by the agents of the unions and the regulators who are focused on OHS. The exclusive practice of a single logic on either side leads to compromise of workers' health and safety and lack of innovation that could achieve both safety and productivity. What is lacking in the work environment of major project delivery is a community logic that fosters peripheral social connections in and out of the project organization to identify needs, inspire new ideas and generate serendipities that can be materialised into innovations. This paper aims to define such a community logic and its role as a fertilizing ground for innovation, to investigate how OHS plays a role to foster the community logic in major projects. The research was guided by three research questions:

- What is community logic and what is not?
- How does the community logic fertilise innovation in major projects?
- How does OHS practice play a role in fostering a community in major projects?

METHODS

The research takes an abductive grounded theory approach (Glaser & Strauss, 1967; Glaser, 1978; Strauss & Corbin, 1990). The community logic was observed during the author's fieldwork on construction sites over the past ten years. Empirical data were collected from ethnographic fieldwork in Hong Kong and Australia during 2012-2017. In field studies of safety and health management practice on site, the manifestation of a production logic and a protection logic were observed in the field and defined in previous publication (Jia et al., 2017). Beyond these two competing logics, a reconciling logic was vaguely observed and articulated (Jia et al., 2019). Built on this, the author went on to explore existing theories to add into her theoretical sensitivity in making sense of some unaccounted observations during the fieldwork, cases that did not subscribe to the two competing logics but effected reconciling the conflict of project goals. These cases were brought to attention when the reviewed theoretical perspectives made them explainable. In an iterative process, a literature review was conducted with the sorting of the data. The literature search started from the key theoretical references of the two previous publications, followed by review of empirical studies that applied or extended these theories. Through synthesis of existing research findings, I define a community logic and a few concepts around it, then articulate the relationships between these concepts.

RESULTS

Community and community logic

What is community?

In the context of construction health and safety, Umeokafor (2018) defines community as "a geographical or geopolitical unit, which identifies culture, interest and ethnicity and is considered as a stakeholder" (p.313). However, Mutch (2021) cites Smith's (1993) account on a 'classic' community (a village) to suggest that a geographical unit could be no more than a collective of unconnected families or exclusive social groups, not necessarily having a community. More essentially, Brint (2001) defines a typology of communities categorised by a geographic-or-choice-based dimension and an



activity-or-belief-based dimension, the choice-based category is further differentiated by its nature of space being concentrated or dispersed. His categorisation resulted in ten types of communities, including (1) communities of place; (2) communes and collectives; localized friendship networks (3) activity-based and (4) cultural-based; elective communities (5) activity-based and (6) belief-based; dispersed friendship networks (7) activity-based and (8) culture-based; (9) virtual communities; and (10) imagined communities. Brint further defined a general concept of community as *“aggregates of people who share common activities and/or beliefs and who are bound together principally by relations of affect, loyalty, common values, and/or personal concern (i.e., interest in the personalities and life events of one another)”* (Brint, 2001, p. 8). Moulaert and Nussbaumer (2005) define community as *“the refutation of mechanist approaches to human relations, and to the acknowledgement of the multiple causalities”* (Moulaert & Nussbaumer, 2005, p. 49).

Hertel et al (2019) define three key factors that distinguish community-led enterprise from capital-led enterprises, including (1) collective agency, (2) willingness to invest private resources and (3) lasting commitment for implementation. These three elements are also the advantages that a community can provide and other logics do not. The second and third elements are both commitments, the willingness of investing private resources is a manifestation of affective commitment; and the ‘lasting’ commitment, which Hertel et al refer as *“an extensive investment of time, expertise, and hard work”* from the community members (Hertel et al., 2019, p. 448). Collective agency, as Hertel et al defined, involves a shared belief and a determination of assuming collective responsibility to tackle some local problems, in contrast to *“waiting for a top-down solution”* (Hertel et al., 2019, p. 447). This collective agency signifies a culture, a collective orientation to make things happen. Mutch (2021, p. 2) contend that *“community is appealed to against the impersonal forces of globalization and managerial capitalism”*. Thornton et al (2013) broaden the community concept to include informal social interactions. Among the various definitions of communities, some commonalities are: connections, relationships, personal involvement and shared cultural-cognitive institutions.

What is community logic?

Thornton et al (2013) define a community logic in addition to six other logics, i.e., family, religion, state, market, profession and corporate. The definition of this community logic is based on a ‘community’ concept defined as a *“territory”* and *“social action that is not restricted exclusively to the satisfaction of common economic needs of the communal economy”* (p.68). This definition of community underpins Lounsbury’s (2007) comparative case study of banks operating on a local community logic and a professional logic respectively, and their different outcomes. Lee & Lounsbury (2015) extend on this line and further emphasize the role of identity, values and tradition in a community logic.

Mutch (2021), however, argues community is not a distinctive institutional order compatible with other institutional orders such as family or state bureaucracy. Mutch’s challenge reflects a fact that many empirical studies on community logic confused the ‘community’ with the ‘community logic’. When they talked about the community logic, they were referring to the culture of a specific community. The seven logics defined by Thornton et al (2013, p. 73) are more of practice in the concrete world. In this sense, Mutch (2021) challenges the validity of defining community as a distinctive logic and rejects community is a logic. However, if we go back to the logics defined by Friedland and Alford (1991), where the logic of capitalist market is the commodification of goods and services; the logic of religion is concerning what is truth and reality; the logic of family is unconditional loyalty to an in-group; the logic of state is rational role structure and administrative order; community does have a higher abstract level to be a logic distinguishable and compatible to the other logics.



What distinguishes a community logic from a professional logic or other logics is the unit of focus, which is on the '**person**', including the **emotional** side of human being and the **authentic connections** among them. In contrast to the capitalism market logic, the state bureaucracy logic and the professional logic, the community logic is a way of holistic, peripheral, people-focused pattern of practice, oriented toward the holistic person. The concept of community logic can be established in comparison with the professional logic: the professional logic is to organize by the logic of the work itself; in contrast, the community logic is to organize things around the people. The community logic is enacted by the multiple interrelations among human members, whereas the richness of connections and information exchange form a breeding ground for innovation.

Not all communities have a community logic

It is to be noted that not all communities are embedded in a community logic. When a community is made of people of a single identity in protective and competitive mind or in a structure of top-down control and lateral isolation, it espouses a culture of hiding information and avoiding exchange of knowledge and ideas. An example is Saxenian's (1994) comparison of two communities, the Silicon Valley and Route 128, the former built on a community logic while the latter more of a corporate logic, resulting in different results of innovation. The connections that shape the community logic involves not only connections of internal work community but also the nature of connections with external communities, as for example, reflected in Marquis et al (2007, p. 934) observation on the nature of corporate social action. In construction projects, it is important to note that a community logic connects different types of people, e.g., crafts workers, technicians and professionals (Emuze, 2018), across levels and boundaries of interest groups.

Community logic and innovation

Community logic brings together experts and lay users

The community logic dismisses the hierarchy between experts and lay users, thus draws on collective wisdom from a pool of diverse actors. Altman and Nagle (2020) explicate a model from cases of United Nation Development Programme (UNDP)'s innovation accelerator labs across the globe. Each of these labs are holistically connected and interacting with local governments, businesses, NGOs, schools and citizens. Meanwhile, the labs are connected with each other in a global network to speed up learning and to disseminate, generalize and relocalise innovations. Altman and Nagle call the sum of this complex network as a 'network of ecosystems' and attribute its success to a portfolio mindset and the power of the collective (p.24).

Community logic fertilizes grassroots innovation through employee participation

The grassroots innovation perspective suggests innovation starts from serendipity which is to be nurtured, fostered, captured and capitalized to turn into product (Loosemore, 2014). The task of making innovation happen is thus turned upside down, from a planning-implementation process to a fostering-enabling process. In the upside-down process, the community logic acts as a filter for members to perceive, interpret and respond to pressures emanate from wider field level logics (Lee & Lounsbury, 2015). Thus the manager's role is overturned from a commander to a coordinator and mentor, to which Sarazin et al describe with a poetic term, 'gardeners' (Sarazin et al., 2021)

Loosemore (2015) redefines two essential features of innovation: (1) Innovation arises out of serendipity and happenstances instead of formal planning process; and (2) Innovation is social, whereas 'community' plays an important role. Loosemore (2015, p. 69) suggests innovation is an outcome of many actor's conscious or unconscious choices: *"In other words, innovation do not*

necessarily emerge by following a predetermined logic but through many possible paths.” It is the community logic that enable the multiple and diverse paths to innovation.

The traditional way of planned innovation is a top-down process where investment of financial and human resources is committed to formalised R&D activities. Top-down practices centred on a single focus, either on safety or on productivity, produce a tightly coupled chain of implementation activities and leaves no room for connecting unrelated clues to conceive new ideas for innovation. The community logic has a loosely coupled orientation. Kesting and Ulhøi (2010) proposed a model to foster employee-driven innovation, which starts from recognising the potential of innovation among ordinary employees as existing resources, which, if sensibly brought out, becomes value for the organisation. Kesting and Ulhøi (2010) define employee-driven innovation as *“deliberate changes to a firm’s bundle of routines or parts thereof that have been ‘driven’ by ordinary employees, who Have no formal authority (i.e., they are not responsible and have no formal right) to be involved in such decisions”*(Kesting & Ulhøi, 2010, p. 72). The definition emphasises the origin of innovations as ‘ordinary’ employees in contrast to a designated specialised team. This essential characteristic highlights its peripheral and vocational nature, which is embedded in the community logic. Kesting & Ulhøi (2010) proposed more detailed mechanism on how to enable employee-driven innovation through increased participation across the employee-manager boundaries. They suggest two actions on the managers’ side: temporary delegation of decision authority to employees, or determination of a frame to enable employee participation. On the employees’ side, they participate by proposing change and collaborating with managers on joint design of participative frame. Reciprocal feedback and modification of the frame are iterated throughout the process.

Community logic brings in diversity, self-initiation, social capital and peripheral communication

O’Mahony & Bechky (2008) identified the differences between a corporate-operated innovation from a community-led innovation in the case of open-source software production. As summarized in Table 1, the former is a top-down formally structured process, while the latter is a bottom-up spontaneous process.

Table 1. Adapted from (O’Mahony & Bechky, 2008, p. 428)

	Corporate operated innovation	Community-led innovation
Initiator/owner	Firm initiate project & owns IP	Individuals initiate & owns IP
Team	Firm-appointed	Voluntary participation. Core team emerges based on merit/effort.
Technical context	Private within the firm boundary	Public, hosted by an individual or nonprofit
Resources	Firm allocated labour and technical resources. Project change with firm strategy and market.	Labour: self-selected volunteers Technical resources: donated. Project continues with people and interest.
Technical specifications	Based on customer analysis	Ideas emerge from diverse participants
Release patterns	Periodical product presentation	Transparent process of development
Customer/users	Lay users	Peers in the profession
User/developer relations	Works of development are structured by the firm, organized according to corporate timetables.	Expanded base of users is a critical part of the development process. Users can progress to become a developer is qualified.



O'Mahony & Bechky (2008, p. 432) recognize a tension between the economic entity and the community, which refer more to the corporate logic and the community logic. In their observation, the top-down model and the bottom-up model are mutually exclusive. In their model, a community logic is a participatory approach to decision making. In view of major construction projects, the project organization is seen as a collective effort instead of a top-down corporate operation. The existence of a community logic in projects enables innovation to develop peripherally within people's extra-job-role activities until it is mature. By keeping the bottom-up initiative peripheral, the innovation is free from market pressure and individual participants are free from managerialism pressure. Such a process gives greater autonomy to the participants in their volunteering activities apart from their formal job accountability.

Duodu and Rowlinson (2019) tested the relationship between human/social/organizational capitals and explorative/exploitative innovations. They found that human capital contributes to both forms of innovation but mediated by social and organizational capital. Human capital in their study means the individuals with their personal education, knowledge and skills. Social capital means the connections in and outside of the organization. Organizational capital means the knowledge and information embedded in organizational structure and routines or captured by network infrastructure. This is in line with the argument here, that a community logic, rather than mere job skills and performance, fosters innovation. Particularly, the community logic underlines the social capital of an organization to foster explorative innovation. In a project organization under delivery pressure, practice is overwhelmingly dominated by exploitation, which excludes problem discovery and problem framing from people's attention. A community logic enables peripheral issues to be explored and informally discussed, thus problems to be framed, constraints to be defined, innovation to be conceived, attended and supported.

The role of OHS in fostering a community logic

Major construction project organizations are fields where two distinctive institutional logics compete and struggle in resource allocation and focus of attention. They are the safety professionals focusing on the OHS procedures and the project professionals focusing on efficient delivery of the project. The people that constitute the professions are embedded in their respective professional logics, but the collective of people, the peripherals of the people and their peripheral connections can form a community logic that generates potential of innovation. This is where we can build up the community logic to allow opportunities of innovation to emerge.

Different characteristics of communities enable innovations of different nature. In a community of strong compliance culture, the connections and inspirations among community members produce innovations of management practice on how to decouple production practice from safety compliance. In a community of open sharing culture and technological insights, innovation that reconciles safety and productivity is to come. Loosemore (2015) suggests six practices to enable grassroots innovation: (1) organizing around opportunities, (2) utilizing corporate identity, (3) taking an emergent view (instead of implementing a predetermined process), (4) being inclusive, (5) collaboration and (6) leveraging social capital. The point of being inclusive is particularly important in opening up the boundaries between interest groups in a project organization to inspire new ideas and enable innovation.

Worker engagement has been a major endeavor in OHS practice in the recent decade (Meldrum et al., 2009; Lawani et al., 2017), initiated by the regulator (e.g. UK HSE), having a strong influence from an OHS professional logic. These 'arranged' participation initiatives manifest more of a corporate logic, but have the potential to be a broker for the development of a community logic in major project



organizations. Stohl and Cheney (2001) define participation as “the discretionary interactions of individuals or groups resulting in cooperative linkages that permeate traditional worker/management boundaries” (Stohl & Cheney, 2001, p. 356). They define a set of participative values and cultures, which can be summarised as: discontent with bureaucracy, appreciation of humanity, prioritising job security, greater job autonomy and practice of democratic values (Stohl & Cheney, 2001, p. 351).

In summary, the community logic enables innovation by enabling the holistic person to function and take initiative. Hertel et al (2019) define local actors’ identity and identification with the community as the key factors for community-led enterprise to flourish are. Therefore, building a project identity is important and essential to foster a community logic that can motivate collective agency and lasting commitment during the course of the project (Hietajärvi & Aaltonen, 2018). The OHS programme within a major project make it possible to hybrid the corporate-operated production work and a community-initiated OHS initiatives to make a fertilizing ground for safety-oriented technological or social innovation.

Three empirical cases observed

Three cases are selected from the author’s fieldnotes of on-site ethnographic study in Hong Kong (2012) and Australia (2015) to illustrate the observed phenomena on how OHS activities played a role in major projects to foster a community logic that helped the generation and diffusion of innovation.

Case 1. Site nurse initiating OHS programmes

This case was observed in an infrastructure project site in Hong Kong. The site nurse of the project was responsible for not only a site clinic but also initiating OHS programmes such as safety quizzes. In summer time, heat stress became a prominent risk to workers. The site nurse walked around site to observe workers. If someone was exhibiting early symptoms, the site nurse took him to the clinic to have a rest in the air-conditioned environment. Having a long-term engagement with the problem, the site nurse started to investigate heat stress management tools such as the Humidex and applied it to site management practice. When a group of academic researchers came to site, the site nurse discussed his confusion of the tools and asked for academic advice to improve the practicality of the system he invented.

Case 2. The Incident Injury Free (IIF) programme in a megaproject

This case was observed in 2015-17 in a megaproject in Australia, where the IIF programme had been an umbrella to accommodate a wide variety of community-building activities. These activities took a very different approach from the top-down compliance-oriented OHS management system, but focused on building relationships and a culture of mutual respect and care among the workforce, change continuous commitment to affective commitment and accepting personal responsibility on safety. It involves activities such as weight loss challenge, weekend sightseeing activities and charity activities. Ideas of new programmes were proposed by the workers and staff at the bottom. The project organizations set up an IIF committee which involved senior management, middle management and workers at the very bottom. Approved proposals were funded by the project organisation. In this way, the bottom-up OHS initiatives helped formulate a project identity and fostered a community logic in the otherwise highly pressured project environment. The programme was not of a single focus on solving OHS problems, but more holistically oriented to develop a community in and around the project organization. It provided care and engagement to the humanity side of the workforce. By engaging workers in healthy and supportive off-work activities, it enables workers to function well at work.

Case 3. A regulator's community-oriented practice

This case was observed in 2015 on a site visit with an experienced regulator in Australia. On one site, the regulator encountered a safety risk where the crane was hoisting and moving concrete boards over head of walking people. The regulator did not immediately give a red tape or warning, but discussed general production issues with the site manager, from which he expressed sympathy to production people's difficulties. On a second site, the regulator visited roof building work where workers were exposed to the risk of fall from height. The regulator took this opportunity to introduce to the site manager a new method of constructing the roof on the ground. In both occasions, the regulator enacted a community logic with his empathizing and sharing practices in the course of which he became a broker for diffusion of innovation.

Conclusions and recommendations

The aim of this paper is to define and articulate a community logic that works as a spring board for innovation in major project delivery. In contrast to a bureaucracy, corporate and professional logics, the community logic is enacted by a focus on the 'person' of the people in projects, including the emotional side of people, and their interconnections peripheral to their formal job duties. It is to be noted that a project organization can have a collective of competitive people but without a community logic. Employee engagement and lateral informal social connections need to be carefully nurtured to foster a community logic. OHS programmes have the potential of being a broker in community-building initiatives in major projects that can inspire and generate innovation not restricted to the safety domain. A workforce in a project organization or a firm has a community dimension outside of the professional logic and outside of the implementation tasks of managerialism. This aspect should be recognized and fostered through peripheral financial and time investment in projects to enable innovation. It helps foster a community logic by building a project identity which can motivate collective agency and lasting commitment to make innovation happen in the delivery of major projects. Practices that enact the community logic focuses on building trust and partnership among the stakeholders to effect a secure environment that nurtures a supportive network in which actors can engage in open exchange of ideas for identifying needs and framing problems, from which innovation emerges. The results suggest that the community logic generates innovation by allowing the holistic person to function and take initiative, bringing in diversity, self-initiative, social capital and peripheral communication into the major project field. Extended OHS or CSR activities help foster a community logic by engaging diverse actors and giving lay users opportunities of participation in the project process. A path model is synthesized from the findings as a recommendation, shown in Figure 1.

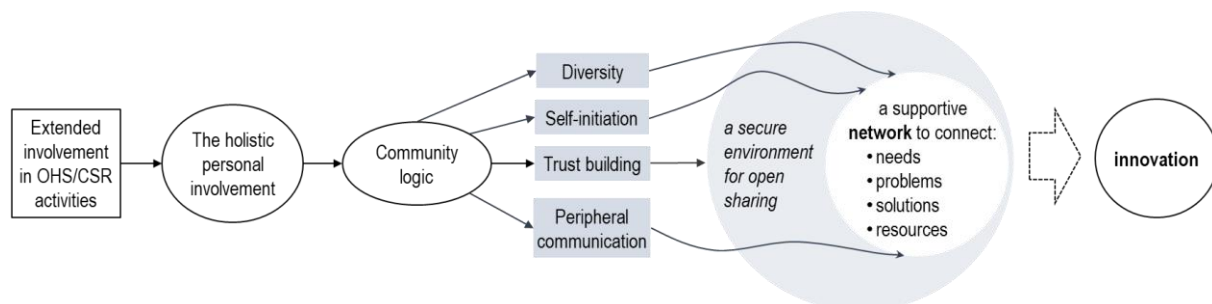


Figure 1. The role of OHS in fostering the community logic for innovation



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Ascending Drones' Safety Risks in Construction

Mostafa Namian¹, Mohammad Khalid¹, George Wang¹, Sharareh Kermanshachi²

¹East Carolina University, USA, ²University of Texas at Arlington, USA

Correspondence: namianm19@ecu.edu

ABSTRACT

Drones or Unmanned Aerial Vehicles (UAVs) have established rapid technological dominance due to their remarkable efficiency and diverse applications. Drones are capable of being equipped with the latest cutting-edge technologies to execute tasks that seemed merely impossible by using traditional methods until now. Contrarily, UAVs can expose construction workers to a new array of safety risks. Construction is among high injury-prone industries, while the safety risk levels can potentially be heightened even more by UAVs. The industry lacks an adequate understanding given the scarce research of drone-associated safety hazards. This study aims to comprehensively identify and investigate drone-related hazards and the associated safety risks in construction and find the relative impact of identified hazards. An online questionnaire survey was developed and distributed among construction experts. The analysis of collected data from an extensive literature review and surveying 54 construction experts revealed a wide range of safety risks, including 'unauthorized trespassing' ranked first followed by 'system malfunction,' and 'distraction.' The research findings can help practitioners and professionals to mitigate safety risks of using drones in their projects and incorporate counterpart preventive measures into their safety management programs.

KEYWORDS: construction, drones, safety risk, UAS, UAV.

INTRODUCTION

Drones come with a wide variety of features that can be utilized at their full capacity for a myriad of purposes and applications in construction, including construction surveying, topographic mapping, site inspections, equipment tracking, project progress monitoring, laser scanning, photogrammetry, and thermal image recording (Asadi and Han 2020; Kayhani et al. 2020; Li and Liu 2019; Liu et al. 2014; Martinez et al. 2020; Oudjehane et al. 2019; Shakhathreh et al. 2019; Tkáč and Mésároš 2019). In contrast, drones can potentially expose workers to unfamiliar hazards in the construction job sites, while construction remains one of the most hazardous industries (OSHA 2018). For example, drone operation failures can lead to collisions, putting human lives and property at risk (Uhlig et al., 2006). Research has found them also to be distracting to spectators, and distraction can significantly impede the safety performance of construction workers (Namian et al., 2018). Despite the necessity to address the safety risks, research exploring and revealing the concealed safety risks remains scarce (Barr et al., 2017; Sanz et al., 2015). Therefore, this research study aims to establish an investigative approach to identify the unknown safety risks in the construction industry. Accordingly, the study's objectives are to (A) investigate and identify the drone-associated safety risks that may expose the project personnel and properties to harm, and (B) study the relative importance of each identified hazard associated with the safety risks. The construction industry is expected to draw practical benefits from this study by educating the construction workforce on unique drone-related risks, enhancing awareness and preparation among them, and deploying preventive measures and effective safety management strategies to mitigate the vulnerability of the project personnel.



LITERATURE REVIEW

Over 1.5 million registered drones, along with 160,000 licensed remote pilots, clearly indicate the rapid proliferation of drones, according to the Federal Aviation (“Remote Identification of Unmanned Aircraft Systems” 2019). To mitigate dangerous attributes and make public operations safer, the FAA has implemented strategies to control the usage of drones. FAA ‘14 C.F.R. Part 107’ regulates the commercial operation of drones, including using drones in construction. According to these federal rules, such drones have to be registered in the FAA system along with their ‘remote pilot in command’ (RPIC), who must be issued appropriate license credentials by the FAA. Although there are exams administered to obtain the pilot license, the drone pilots will be examined on FAA regulations that have been criticized to significantly address safety concerns (Calandrillo et al. 2020).

Like other sectors, the construction industry has also adopted diverse drone applications for multifarious purposes because of its capability to provide high-quality video and photographic data (Martinez et al. 2020). Due to the facile accessibility and economic practicality of integrating drones in construction projects, it has been detected as a leading industry to massively adopt drones (Oudjehane et al., 2019). However, unlike other industries, construction is suffering from high rates of occupational accidents, making it considerably more vulnerable to the safety risks of drones in workplaces. The construction workplace is one of the most complex setups consisting of many hazards, and adding newer types of hazards can result in compromising the safety management plans (He et al., 2015). Drones may bring in the possibility of unknown risks comprising multiple operational challenges, including flight instability, abrupt termination, loss of control and onboard power, the capability to cope with dynamic nature, and premature autonomous landing (York, Al-Bayati, and Al-Shabbani, 2020). Drones are quite vulnerable to various operational challenges such as GPS ‘spoofing’ (Rao et al. 2016), loss of control from signal interference (Parush 2006), low flight reliability and susceptibility to harsh weather (Li and Liu 2019), high energy consumption and limited power storage (Shakhatreh et al. 2019), and most importantly human-generated errors (Neff and Garman 2016).

Moreover, drone integration can enact a newer range of distraction-based unsafe behavior accountable for catamorphic accidents (Namian et al., 2018). Drones contain the capability of seizing attention. The flight of drones is proven to be an interesting sight often grasping the interest of the working personnel involved in carrying out their day-to-day monotonous jobs (Li and Liu 2019; Martinez et al. 2020). Studies have identified workers to stop their ongoing work because of distraction during the drone’s fly-by above them (Xu et al. 2020). This can lead to perceptual misinterpretation of any safety risk, and the consequences can be fatal as the construction jobs are highly risk-prone in nature.

Despite endless opportunities with drones that are yet to be explored, there is scarce relative research to realistically identify drone-related hazards and associated safety risks. This research study takes a unique attempt to investigate the possible hazards associated with drone-related applications in the construction sector and evaluate their relative impacts in order to develop effective training materials that the industry can implement. There is a dire need to develop contingency measures for the personnel to mitigate the potential risks. Moreover, the professionals and practitioners who have already adopted drone-related technology in their projects can also greatly benefit from the research findings and take precautionary actions to limit the impact of the safety hazards.

RESEARCH METHODOLOGY

Despite having drone-related experience in construction and the FAA remote pilot license, the researchers ensured the study be free from any sort of bias. An active ‘UAV Mapping Specialist’ with FAA pilot license and OSHA 30 training was involved in serving as the research advisor. The research team conducted a brainstorming session to discuss the details of the research study.

A comprehensive review of the previous literature was carried out from various research database sources such as ASCE Library, Science Direct, Google Scholar, Mendeley, and Scopus using keywords such as 'UAV,' 'Unmanned Aerial Vehicle,' 'UAS,' 'Unmanned Aerial System,' 'drone,' 'construction,' 'safety,' 'accident,' and 'incident.' Different domains outside of construction were considered for the literature review followed by extraction of a preliminary list of hazards. Based on experience, suggestions, and findings, an advanced questionnaire survey was developed targeting specific construction personnel across the nation. The survey was reviewed and amended according to the research advisors' comments and suggestions. Finally, the survey was approved as 'exempted' before mass distribution by the University and Medical Centre Institutional Review Board (UMCIRB) of the East Carolina University (ECU).

Survey questionnaire

The survey questionnaire for this study was designed to involve assorted questions ranging from participants' general demographic information to their open-ended opinions and perceptions on various risk-related issues of drones in the construction. Upon sharing the demographic information, the participants were asked about their experiences with drones, either direct or indirect, and if they had come across any situation that can be described as dangerous. In order to gain a more detailed understanding of their risk-perceptions on drones, a 7-point Likert scale ranging from 0 ("extremely low") to 7 ("extremely high") was incorporated for the participants to express their ratings. The participants were asked to list any hazard that was not included in the questionnaire. However, the results indicated that the participants identified no new hazards apart from the ones already listed. Moreover, the participants also shared their suggestions for safety measures to mitigate the risk and predictions on the future of drones.

Data collection and research participants

The study was carried out during the unprecedented difficult times of COVID-19. Therefore, the online data collection method was adopted instead of the original planning of an in-person survey. A substantial number of sources from the Internet were scavenged to identify key personnel based on their relevant experience in the study. Since there was a lack of data in terms of UAV-related operations in the construction sector, the snowball sampling technique was used to distribute the questionnaire. Snowball sampling is a common method used in construction safety-related research (Loosemore and Malouf 2019; Wachter and Yorio 2014). The researchers developed the questionnaire in Qualtrics and randomly distributed it to the target audience through emails, and the responses were recorded progressively. The survey concluded with 63 participants from a wide range of construction organizations and UAV service providers responding over a period of three months. A total of 54 responses were filtered for further consideration as the remaining (nine) responses were discarded due to insufficiency of completion. The retained responses included detailed demographic information on the participants' including their experience (see Table 6), position and specialty (see Table 7), safety training (see Table 8), and drone pilot credentials (see Table 9).

Table 6. Demographic information of the participants – construction experience (years)

0-5	5-10	10-20	20-30	>30
24	8	9	4	9
(44%)	(15%)	(17%)	(7%)	(17%)



Table 7. Demographic information of the participants - position

(Assistant) Project Manager	CEO/ Owner	Project Engineer	Safety Specialist	UAV Specialist	Other Managerial	Other
5 (9%)	11 (20%)	7 (13%)	3 (6%)	6 (11%)	9 (17%)	13 (24%)

Table 8. The participants' safety training status

OSHA 30	OSHA 10	None
15* (28%)	13* (24%)	35 (65%)

* 7 (13%) participants had both OSHA 10 and 30

Table 9. The participants' drone pilot credentials

With License	Without License
34 (63%)	20 (37%)

The participants were from a diverse range of project types (i.e., commercial, residential, etc.). The results depicted that more than 70% of the participants reported having direct or indirect experience with the applications of drones in their respective job sites; 'progress monitoring and documentation' followed by 'site mapping' and 'inspection' were recorded to be the most commonly cited applications of drone-related usage in the construction.

The recorded dataset was examined carefully to develop categorized accident experiences, drone applications based on purposes, potential safety risks, and probable preventive measures. The research team utilized statistical software, namely, XLSTAT 2019, to analyze the data for any significant differences of perception among the workforce that can help to improve the overall safety performance.

DATA ANALYSIS AND RESULTS

The associated safety risks of drones

The participants shared their drone-related experience for various activities, projected risk factors, accidents, and safety measures. They also rated the severity of several drone-associate safety risks, and the average was calculated accordingly with the Relative Impact Index (RII) using Equation 1 to prioritize and sort them from the highest to the lowest-rated element (see



Table 10).

$$RII_i = \frac{\sum_{i=1}^n W_i}{(AN)} \quad (1)$$

A = maximum possible rating (7);

W = summation of all participants' ratings for each question;

N = number of recorded responses corresponding to each question.

Table 10. Safety risk questions based on their Relative Impact Index (RII).

#	Safety Risk	RII	Rank
1	Collision with working personnel causing bodily injury	0.407	7
2	Collision with property causing damage to the assets and surrounding personnel	0.457	4
3	Distraction causing loss of concentration and erroneous maneuvers of the construction equipment resulting in severe accidents	0.474	3
4	Obstruction of the vision during critical lifting or installation operations	0.415	6
5	Interference of radio signal causing communication hazard	0.450	5
6	Rotating blades of drones causing a fire hazard in the controlled environments	0.310	8
7	Drones capable of conducting lifting operations creating the risk of malfunctioning and crashing, or falling onto a person or property	0.516	2
8	Unauthorized trespassing and collection of sensitive information breaching the personal property rights	0.534	1

Data analysis suggested that the participants having safety training perceived a higher level of safety risk compared to the participants with no safety training (see Figure 9). A statistically significant difference (p -value < 0.1) was found between the two groups for the distraction-related question (Q3) when the two-sample 't-test' was run. This leads to the proposition that the participants with safety training may have acquired certain skills from the safety training to evaluate drone-related safety risks partially. It is good to note that a Shapiro-Wilk test was conducted to determine whether the differences in two could have been produced by a normal distribution (Razali and Wah 2011). The results of the Shapiro-Wilk test were not significant based on an alpha value of 0.05, $W = 0.94$, $p = .235$. This result suggests the normality assumption is met. Levene's test was conducted to assess whether the variances of the two groups were significantly different. The result of Levene's test was not significant based on an alpha value of 0.05, $F(1, 36) = 1.88$, $p = .179$. This result suggests it is possible that the two groups were produced by distributions with equal variances, indicating the assumption of homogeneity of variance was met.

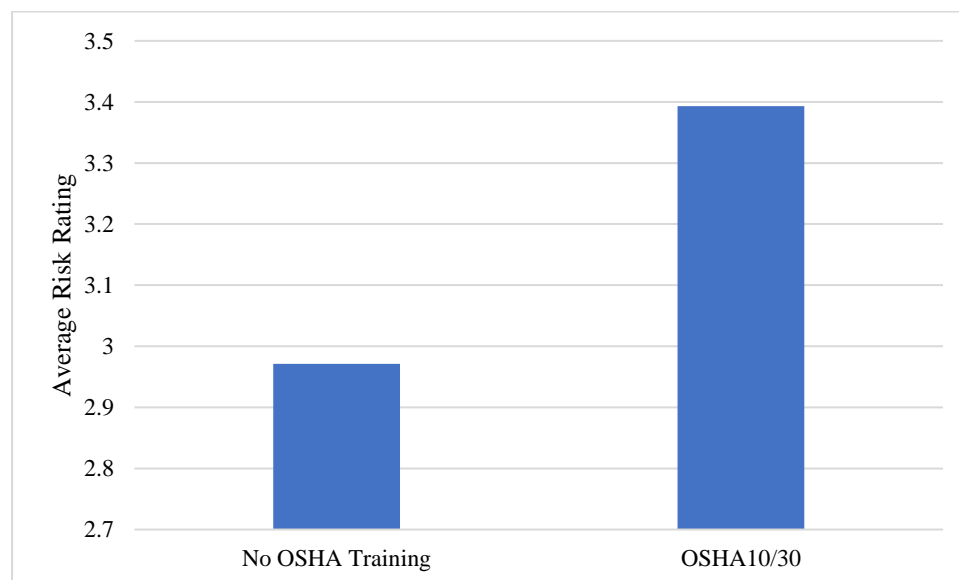


Figure 9. Average risk rating responses based on safety training.

Similarly, the risk rating responses were analyzed statistically between two groups based on having the FAA remote pilot license, which revealed a statistically significant difference (p -value < 0.0001), as shown in Figure 10. Therefore, each question was individually tested for the statistical difference, which resulted in the display of five questions based on safety risks in terms of distraction, fire hazard,

visibility, lifting failure, and unauthorized trespassing that had significant statistical difference perception of the respondents (see Table 11).

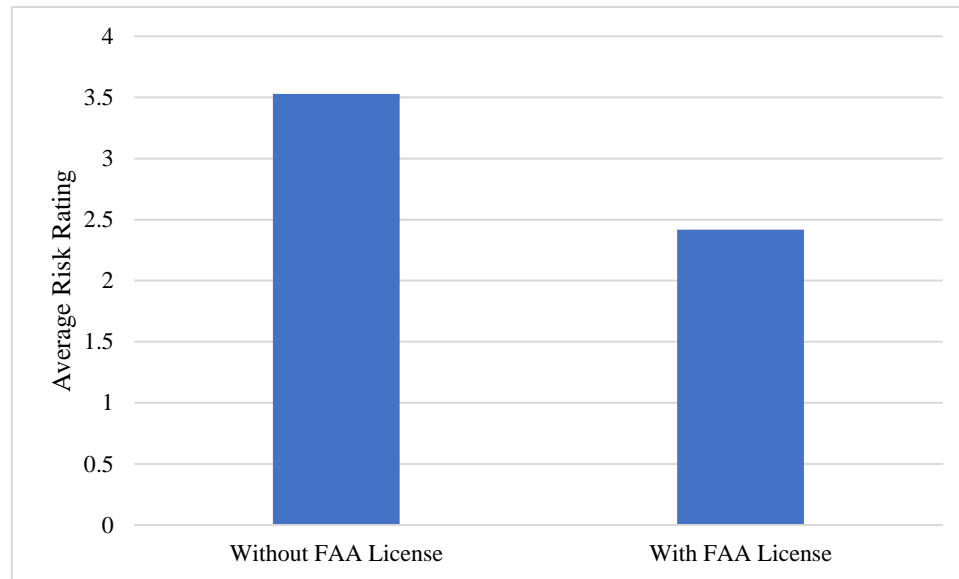


Figure 10. Average risk rating responses based on the FAA remote pilot licensure.

Table 11. Statistical analysis results (licensed vs. non-licensed).

Questions	p-value
Q1. Collision with Personnel	0.157
Q2. Collision with Property	0.246
Q3. Distraction	0.056**
Q4. Visibility Obstruction	0.038*
Q5. Radio Signal Interference	0.229
Q6. Fire Hazard	0.051**
Q7. Failure of Lifting	0.011*
Q8. Unauthorized Trespassing	0.028*

* p-value < 0.05

** p-value < 0.10

The researchers also classified and analyzed the responses based on the factor of having any drone-related experience or not as well as having direct or indirect experience. The results showed a clear difference in their risk perception between the participants who had associated experiences. In both cases, participants with drone-related experience perceived a higher level of the safety risk, and so did the participants who had direct experience with the drone compared who did not have it (see Table 12).

Table 12. Statistical analysis results (direct vs. no-direct experience).

Questions	p-value
Q1. Collision with Personnel	0.037*
Q2. Collision with Property	0.364
Q3. Distraction	0.094**
Q4. Visibility Obstruction	0.038*
Q5. Radio Signal Interference	0.095**
Q6. Fire Hazard	0.016*
Q7. Failure of Lifting	0.177



Q8. Unauthorized Trespassing 0.163

* p-value < 0.05

** p-value < 0.10

Preventive safety measures

The survey also encompassed the suggestions from participants about the preventive measures of the drones, where 29 out of 54 participants expressed their recommendations. Their recommendations reveal that among a wide range of preventive measures, 'engagement of qualified and competent flight crew,' 'proper model selection and maintenance of drones,' and communication and awareness' were the most popular of all (see Table 13).

Table 13. Preventive measures recommended by the surveyed experts.

#	Recommended Preventive Measures	Frequency
1	Engagement of qualified and competent flight crew	10
2	Proper model selection and maintenance of drones	10
3	Awareness and communication	7
4	Drone operation during off-time	6
5	Following standard regulations	6
6	Flying proximity/No-fly zone	5
7	Pre-flight checklist	5
8	No flight over people	5
9	Automated pre-programmed flights	3
10	Avoidance of interference and trespassing	3

DISCUSSION

Even if UAV applications are apparently perceived to be harmless, this study explored and identified an array of potential safety risks that can impose a great degree of danger to people and properties in construction. The participants perceived all of the eight identified hazards to impose the extent of safety risks on construction projects. A substantial difference in safety perception was detected between the participants based on their safety training and FAA remote pilot license status. On the other hand, personnel with prior drone usage experience tend to perceive lower levels of safety risks which can be attributed to becoming desensitized to the associated safety risks (Perlman et al., 2014). A substantial number of participants (16%) reported having experienced drone-related accidents, while 17% of the total participants reported that they have heard about drone-related mishaps from their professional peers. The discovered safety problems and subjective perceptions of UAVs in construction show how the rapid UAV integration rate may present many new intrinsic hazards to unprotected construction employees, inflicting considerable impact. Relatedly, stakeholders may proactively provide the workforce with necessary training and equipment, which would not otherwise be conceivable without identifying such safety concerns. The suggested preventive measures from the participants open up an outstanding possibility to explore and develop an appropriate safety management system that can successfully mitigate the safety risks. In addition to the engagement of expert and experienced flight crews, the participants also advocated selection of specific and appropriate drone models, timely maintenance, promulgation, and general awareness of drone usage, flying during off-hours, and strict adherence to mandated regulations.

LIMITATIONS AND FUTURE RECOMMENDATIONS

The study unveils a paradigm of drone-related safety issues present in the construction. However, the research team was limited to certain factors, especially being obligated to conduct the interview in the virtual form with a relatively small sample size due to the unprecedented situation of COVID-19. This study does not validate and/or justify the identified risks in detail for the purpose of developing specialized safety management systems. The lack of empirical results barred replicating potential



scenarios to carry out simulations for the construction professionals. Future research should overcome the limitations by focusing on conducting practical experiments with the aid of advanced data extraction mechanisms (i.e., eye-tracking) in real or simulated construction environments.

CONCLUSIONS

The world is on the verge of mass integration of drone technologies in every other commercial sector, including construction, due to the remarkable benefits and applications. However, the concealed safety challenges of the drones remain uncharted until the fate of the workforce becomes heavily endangered without necessary safety management strategies. The construction sector is widely known for suffering from high rates of occupational accidents that may possibly increase with the implantation of additional sources of hazards such as drones. With emerging proliferation, drones can become a potential medium of threats to people or properties present in construction workplaces. With a lack of pro-active education, training, and management based on this emerging drone technology, the unidentified workplace hazards can potentially claim invaluable lives and putting a halt to regular productivity. This study aims first to investigate and identify the drone-associated safety risks and then examine the relative importance of each identified hazard and the associated safety risks. To achieve the objectives, 54 construction experts across the United States were surveyed to solicit their experience and expertise. The participants with FAA remote pilot licenses appeared to perceive lower levels of risks associated with drones. On the other hand, the surveyed experts who had received safety training expressed more concerns than those who did not have such formal training. The results reveal robust information on the identified adverse safety outcomes of drones, including eight critical threats, among which 'unauthorized trespassing,' 'system malfunction,' and 'distraction' are the most vital. Construction sites are stuffed with essential operations imposing a certain extent of a safety risk to the workforce. Therefore, it is necessary to deploy significant safety management schemes with adequate knowledge of this new technology to efficiently mitigate the dynamic range of such safety hazards. To address this necessity, the results of this study suggest 'engagement of qualified and competent flight crew,' 'proper model selection and maintenance of drones,' and 'awareness and communication' as effective safety measures along with several other recommendations to mitigate the safety risks of drones in construction. The professionals and practitioners who aim to adopt drones in their construction projects can benefit from this research study to properly train their employees and implement effective safety measures to prevent occupational accidents.

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FAMILY ROLE BLURRING AND CONFLICT: THE CASE OF SOUTH AFRICAN CONSTRUCTION PROFESSIONALS

Rita Peihua Zhang¹ and Paul Bowen²

¹School of Property, Construction & Project Management, RMIT University, Melbourne, Australia

²Department of Construction Economics and Management, University of Cape Town, South Africa

Correspondence: Paul.Bowen@uct.ac.za

ABSTRACT

Many construction professionals play a role in both the work- and family-domains, frequently engage in role transitions and role blurring, and often juggle between work and family demands. The proliferation of communication technologies makes the boundaries between work and family more blurred and permeable than ever. Using data collected via an online survey, the relationships between work demands, role blurring, work-to-family conflict (WFC), and health and wellbeing consequences among South African construction professionals were explored using structural equation modelling (SEM). Work pressure was found to be a pivotal antecedent to all role blurring activities i.e., after-hours work contact, pre-occupation with work, and multi-tasking between job tasks and family tasks whilst at home. Work contact is directly predicted by work hours, but work hours indirectly affect pre-occupation and multi-tasking via the mediating role of work contact. All role blurring activities are positively associated with construction professionals' experience of work-to-family conflict, subsequently leading to depression and sleep impairment. The results also indicate that depression affects the quality of sleep and that construction professionals are likely to consume use alcohol to cope with sleep problems. Depression was found to be negatively associated with alcohol consumption, which calls for a more fine-grained analysis of the complex inter-relationship. This study provides evidence that excessive work demands can interfere with the family domain through the boundary permeating mechanism of role blurring, ultimately affecting construction professionals' health and wellbeing. This study highlights the importance of appropriate work design with manageable workloads and reasonable work hours. It also points to the promotion of boundary tactics for reducing work-family role blurring and conflict experienced by construction professionals, providing valuable pointers for organisations in the construction industry.

Keywords: Role blurring, work-family conflict, health and wellbeing, alcohol consumption, construction professionals.

INTRODUCTION

In recent years there is increasing acknowledgement that individuals' work-life and family-life are intertwined and have a reciprocal influence on each other (Allen et al., 2014), generating considerable research interest in examining work-family boundary dynamics. For example, Clark (2000: 750) developed the "border theory" to explain how individuals "*manage and negotiate the work and family spheres and borders between them to attain balance*", and Ashforth et al. (2000) proposed the "boundary theory" to describe how individuals create and maintain boundaries to order the environment around them and assign specific meanings to different domains (e.g., work and family). These theories provide a useful theoretical basis for understanding how work-family integration and boundary-blurring may impact individual work performance and well-being (Desrochers et al., 2005). Many employees play a role in both the work- and family-domains, frequently being involved in role transitions and role blurring, and often trying the navigate between work and family responsibilities.



Moreover, in the current digital era, the boundaries between work and family are more blurred and permeable than ever due to the proliferation of communication technologies (Kossek, 2016).

Through the theoretical lens of boundary theory, this study aims to extend existing research on the work-family experiences of construction professionals by exploring: 1) the antecedents of work-family role blurring; 2) the relationship between role blurring and work-to-family conflict, and 3) the consequents of work-to-family conflict.

LITERATURE REVIEW AND HYPOTHESES

Work conditions and role blurring

The permeability of work and family boundaries can be affected by demands from either the work domain or the family domain. High boundary permeability is associated with high levels of boundary-spanning demands such as role blurring activities (Voydanoff, 2005). The construction industry is widely recognized as an industry characterised by high levels of workplace stress. Work demands in relation to work pressure and work hours have consistently been identified as the most critical work stressors experienced by construction professionals (Lingard & Francis 2005).

Tausig and Fenwick (2011) define work pressure as individual subjective assessment that is produced from objective work conditions and individual psychological disposition. Individuals who experience elevated work pressure are likely to feel overwhelmed by the amount of work to be completed and perceive that the demands of their job exceed the time and energy available to do the work (Schieman & Young, 2013). This perceived work pressure may lead employees to devote additional non-work time to meet job demands and stay connected with work-related activities (and thoughts) beyond the conventional parameters of the workplace (Schieman & Glavin, 2016). Previous research has revealed a significant association between work pressure and the frequency of work-family role blurring activities (Schieman & Glavin, 2016). It is hypothesised that the work pressure experienced by construction professionals increases boundary permeability and predicts all role blurring activities:

H1: Work pressure is positively related to pre-occupation with work after-hours

H2: Work pressure is positively related to multi-tasking at home

H3: Work pressure is positively related to after-hours work contact

Work hours are a time-based job demand, and studies have revealed that long work hours can lead to interference between work and family responsibilities (Adkins & Premeaux, 2012). Few studies have examined the impact of work hours on boundary permeation and role blurring, although Glavin and Schieman (2012) drew attention to the phenomenon of “*stress of higher status*” i.e., professionals who work longer hours may take more senior and demanding job roles and assume more work-related responsibilities than do others and are thus more likely to devote non-work time to deal with work-related issues. Therefore, it is hypothesized that:

H4: Work hours are positively related to pre-occupation with work after-hours

H5: Work hours are positively related to multi-tasking at home

H6: Work hours are positively related to after-hours work contact

Role blurring and work-to-family conflict

Role blurring is a form of boundary-spanning demands (Voydanoff, 2015). Boundary-spanning demands are concerned about the trade-offs derived from the continuum of segmentation to integration across domains (Voydanoff, 2015). Segmentation is associated with low permeability between work and family domains, but a high level of difficulty in transitioning from one domain to another domain. Segmentation can lead to time- and space-based boundary-spanning demands such as commuting time and long-distance travel for work (Voydanoff, 2015). Integration makes the



transitions between domains comparatively easy but is associated with high levels of permeability, which leads to overlaps between work and family activities and high levels of role blurring (Voydanoff, 2015). The boundary-spanning demands of role blurring focus primarily on space-based blurring e.g., bringing work home, receiving job contacts at home, and work-family multi-tasking (Voydanoff, 2015). Role blurring may add to work-to-family conflict as it creates interruptions and distractions in the family domain, encroaches on time and energy that should be spent on family roles and limits individuals' full engagement in performing family roles (Glavin & Schieman, 2012). Schieman and Glavin (2008) reported that role blurring activities, including receiving work-related contact outside of normal work hours, bringing work home, and work-family multi-tasking are positively associated with work-to-family conflict. In the construction industry, Bowen et al. (2018) reported that after-hours work contact is positively related to professionals' experiences of work-to-family conflict. Thus, it is hypothesized that role blurring activities increase work-to-family conflict for construction professionals:

H7: Pre-occupation with work whilst at home is positively related to work-to-family conflict

H8: Multi-tasking at home is positively related to work-to-family conflict

H9: After-hours work contact is positively related to work-to-family conflict

Work-to-family conflict and health-related consequences

The negative influence of work-to-family conflict on individuals' psychological health and well-being is well-documented (see, for example, Amstad et al., 2011). In the South African construction industry context, Bowen et al. (2018) found that work-to-family conflict was positively associated to professionals' experiences of psychological distress and sleep problems. More recently, Bowen and Zhang (2020) reported that work-to-family conflict also indirectly affects construction professionals' alcohol use behaviors through the mediating effect of sleeping problems.

McTernan et al. (2016) identified the relationship between work-family conflict and psychological health through the theoretical lens of the stressor-strain process. In essence, the experience of work-to-family conflict is a stressor that may cause psychological strain, which subsequently leads to mental disorders such as depression. In turn, experience of work-to-family conflict and depressive symptoms may also lead to sleep problems (Hämmig et al., 2009) as they may cause concerns surfacing in the mind which contribute to sleep irregularities (Cropley et al., 2006). Thus, it is hypothesised that:

H10: Work-to-family conflict is positively related to depression

H11: Work-to-family conflict is positively related to sleep problems

H12: Depression is positively related to sleep problems

Work-family research suggests that the stressor of work-to-family conflict can affect employees' health-related behaviours in a number of ways, including alcohol consumption (Wolff et al., 2013). According to Frone (2008), alcohol use can usefully be explained by tension reduction theory (Conger, 1956), which suggests that substance use can reduce tension / strain resulting from stress exposure. Consistent with the tension reduction perspective, Wolff et al. (2013) established that employees who experience depression and anxiety arising from work-family conflict are likely to use alcohol consumption to cope with the negative emotions. Similarly, employees who suffer from sleeping problems due to work-family conflict may also use alcohol consumption as a coping mechanism, as alcohol consumption has been reported as a convenient, self-medicated, cost-effective and low-risk hypnotic used in the self-treatment of sleep irregularities (Stein & Friedmann, 2005). Therefore, it is hypothesized that:

H13: Depression is positively related to alcohol consumption

H14: Sleep problems are positively related to alcohol consumption

The proposed research model is depicted in Figure 1, which indicates the various hypotheses offered *a priori* based on the literature review.

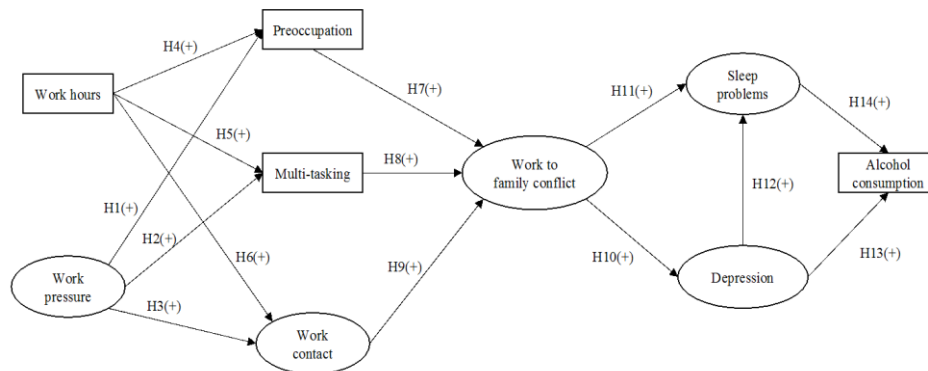


Fig 1. The hypothesized research model

RESEARCH METHOD

Measures

The epistemological assumptions underpinning this study are of a positivist nature. The analysis and interpretation of the data adopted an objectivist / determinist ontological paradigm. The quantitative study utilized a questionnaire survey for data capture. Table 1 lists the variables, sample items and point of scales. The questionnaire was based on an instrument previously employed by Schieman and Young (2013). The Schieman and Young (telephonic) questionnaire was employed in a national Canadian study by the Department of Psychology, University of Toronto, to explore work, stress, and health in the Canadian general working population. Bowen et al. (2018) modified the questionnaire to suit online administration to registered construction professionals in South Africa (de facto part of a working population). In all instances higher scores indicate higher levels of the construct of interest.

Table 1. Scale items for composite variables and associated measures

Construct	No. of items	Sample item	Point of scales
1. Workload pressure (WP) (Score range: 3-15)	3	In the last 3 months, how often did: 'You feel overwhelmed by how much you had to do at work?' (WP1)	1 = "Never" to 5 = "Very often"
2. Hours of work (Work hours) (1-7)	1	'In a typical week, how many hours do you usually work on job-related work?'	1 = "31-35 hours" to 7 = "Above 60 hours"
3. Preoccupation with work (Preoccupation) (1-5)	1	In the past 3 months: 'How often did you think about work-related things when you were not working?'	1 = "Never" to 5 = "Very often"
4. Multi-tasking at home (Multi-tasking) (1-5)	1	In the past 3 months: 'How often did you try to work on job tasks and home tasks at the same time while you were at home?'	1 = "Never" to 5 = "Very often"
5. Work contact (WC) (3-15)	3	In the past 3 months: 'How often did you get job-related emails or text messages out of normal office hours?' (WC2)	1 = "Never" to 5 = "Very often"
6. Work-to-family conflict (WFC) (4-20)	4	In the past 3 months: 'How often did you not have enough time for the important people in your life because of your job?' (WFC1)	1 = "Never" to 5 = "Very often"
7. Depression (DEP) (5-20)	5	'You often feel helpless in dealing with problems of life?' (DEP4)	1 = "Strongly disagree" to 4 = "Strongly agree"



8. Sleep problems (SP) (3-15)	3	In the past month, how often have you: ' <i>Had trouble falling or staying asleep?</i> ' (SP1)	1 = "None of the time" to 5 = "All of the time"
9. Alcohol consumption (AU) (1-25)	-	= Frequency of drink x Amount of drink	1 = "Once a month or less" to 5 = "Everyday"
	1	<u>Frequency</u> : ' <i>During the past 3 months, how often did you drink alcoholic beverages?</i> ' (AU1)	1 = "Never" to 5 = "More than once a week"
	1	<u>Amount</u> : ' <i>How often in the past 3 months, have you had 5 or more drinks on one occasion?</i> ' (AU2)	

Primary data collection

Professional registration is mandatory in South Africa, so registration / membership lists are excellent proxies for full populations. The population consisted of architects (N = 3389), engineers (N = 2431), quantity surveyors (N = 1859), and project and construction managers (N = 1868) registered with their respective statutory councils. A total of 9547 professionals were emailed by their respective statutory bodies, provided with an explanatory letter and a URL for online access to the questionnaire, and asked to participate in the survey. A minimum sample size of 370 is desired with this population size following the sampling technique of Cochran (1963). A total of 864 useable responses were received, representing 9% of the total construction professional population in the country.

Data analysis method

Confirmatory factor analysis (CFA) using AMOS 25 was first performed to verify the factorial structure of items underlying the five latent variables. CFA was conducted according to procedures recommended by Hair et al. (2014), including recommended thresholds for model fit indices. Five critical model fit indices were applied to determine the degree of fit: χ^2/df ratio (less than 4); the Tucker Lewis TLI (.90 and greater); Bentler CFI (.90 and greater); RMSEA (.08 and less); and Hoelter (200 and greater). A factor loading of 0.5 is minimally accepted and a loading of 0.7 is considered satisfactory (Hair et al., 2014). Once the factorial structure had been validated, the internal consistency of the scales was then assessed using Cronbach's alpha. Higher value means better internal consistency and Cronbach's alpha > 0.7 is considered acceptable (Hair et al., 2014). Thereafter correlation analysis of the factors was undertaken. Then the proposed theoretical model was subject to path analysis using structural equation modeling (SEM) to test the hypothesized relationships.

RESULTS

Data cleaning and missing values

The dataset ($n=864$) was examined for anomalies and subjected to missing value analysis. Thirteen cases had missing values exceeding 10% and were deleted, resulting in a final dataset of 851 cases. Little's MCAR test indicated that item missing values were missing completely at random ($\chi^2 = 1922.53$, $df = 1929$, $p > .05$) and these were imputed using the expectation-maximization (EM) algorithm.

Demographic characteristics of the final dataset ($n=851$)

Among the final dataset there were 293 (35%) architects, 292 (35%) engineers, 180 (21%) quantity surveyors, 34 (4%) construction managers (within contracting organizations), and 48 (6%) project managers (independent consultants). Four participants did not identify their occupation. The majority of respondents were partners or directors of the firm (59%), 10% were associate partners, and 31% were salaries employees. Ages ranged from below 25 years to over 60 years, with the mean age in the interval 45-49 years. Most participants were male (81%), and either married (80%) or living with a partner (7%). Forty-eight percent reported children under 18 years old living at home, and most had either one (14%) or two (28%) children.

Confirmatory factor analysis

All correlations were significant (one-tailed) $p < .001$ and the direction of all associations was positive. A measurement model based on the five latent factors was specified and tested. Work hours, pre-occupation with work, multi-tasking, and alcohol consumption were not included in the measurement model as constructs but were included in the structural model as measured items. Output indices for the 18-item, 5-factor model indicated an acceptable fit to the data (χ^2/df ratio = 3.604; IFI = .961; TLI = .952; CFI = .961; RMSEA = .055, CI 95% (.050 - .061), and Hoelter (95%) = 287). However, items DEP3 ('you can do anything you really set your mind to?' [reversed]) and SP3 ('woke up feeling refreshed?' [reversed]) indicated unacceptably low factor loadings and were removed. The resultant model proved a very good fit to the data (χ^2/df ratio = 2.960; IFI = .977; TLI = .970; CFI = .976; RMSEA = .048, CI 95% (.042 - .055), and Hoelter (95%) = 360). All factor loadings were strong and statistically significant. Good to excellent internal consistency was indicated: workload pressure ($\alpha = .92$), work contact ($\alpha = .84$), work-to-family conflict ($\alpha = 0.91$), depression ($\alpha = .81$), and sleep problems ($\alpha = .78$). For all five scales the corrected item-total correlation values exceeded .50 (indicative of very good discrimination).

Developing and testing the structural model

Based on the conceptual model (Figure 1), an integrated structural model was specified and tested. The initial model was a satisfactory fit to the data (χ^2/df ratio = 4.493; $p < .001$; IFI = .936; TLI = .923; CFI = 0.936; RMSEA = 0.064, CI 95% (.059 - .069); and Hoelter (95%) = 226), indicating the applicability of the theoretical framework. The modification indices indicated the need for direct relationships between work pressure and work-to-family conflict, between work contact and pre-occupation with work, between work contact and multi-tasking, and between work pre-occupation and sleep problems, as well as for the error-terms of WFC1 ('how often did you not have enough time for the important people in your life because of your job?') and WFC2 ('how often did you not have the energy to do things with the important people in your life because of your job?'), and DP1 ('you have little control over the things that happen to you?') and DP2 ('there is really no way you can solve some of the problems you have?'), to be correlated. The resultant model (see Figure 2) presented a very good fit to the data (χ^2/df ratio = 2.287; IFI = .977; TLI = .972; CFI = .977; RMSEA = .039, CI 95% (.034 - .044), and Hoelter (95%) = 445).

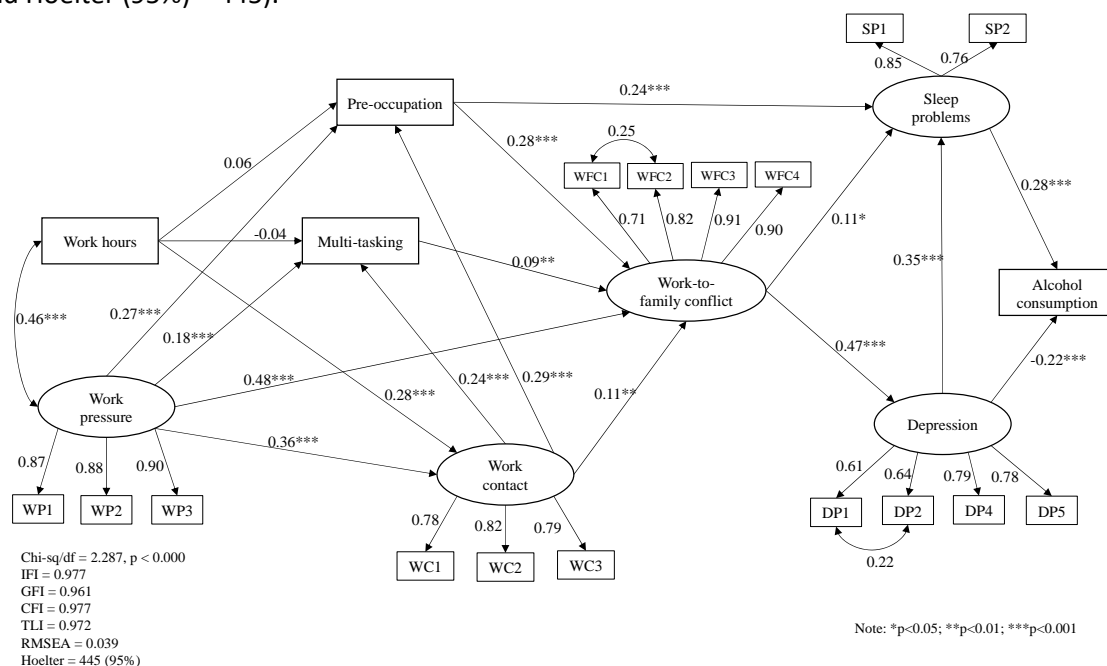


Fig 2. The final structural model



DISCUSSION OF THE RESULTS

Antecedents of work-family role blurring

Work pressure is positively associated with various role blurring activities, including pre-occupation with work when at home, multi-tasking between work and home tasks when physically at home, and after-hours work-related contact. These findings align with Schieman and Glavin (2016) who reported that work pressure is an important determinant of boundary permeability and role blurring.

The results indicate that, when faced with high levels of work pressure, construction professionals are likely to devote additional non-work time to meet job demands i.e., demands from the work domain spill over to the family domain through role blurring activities. This study adds to the previous research of Schieman and Young (2013) by showing that, in addition to work contact being an outcome of work pressure, multi-tasking and pre-occupation with work whilst at home are also direct consequences of work pressure. The findings therefore support Hypotheses H1, H2, and H3.

Work hours were found to be positively associated with work contact. However, contrary to expectations, work hours did not directly predict pre-occupation with work or multi-tasking whilst at home. The results partially align with Glavin and Schieman (2012), who reported that long work hours are associated with various role blurring activities. Glavin and Schieman (2012, p.92) drew attention to the fact that role blurring is associated with “*the stress of higher status*”. In line with this observation, professionals who work longer hours often hold more senior positions and assume greater job responsibilities than do their counterparts and are more likely to receive work-related contact outside of working hours. Although there are no direct significant associations between work hours and each of multi-tasking and pre-occupation with work, work hours *indirectly* affect multi-tasking and pre-occupation with work via work contact. The current study adds to Glavin and Schieman (2012) by showing that work hours influence different aspects of role blurring in different ways, thereby supporting Hypothesis H6, but not supporting Hypotheses H4 and H5.

The significant association between work demands and role blurring is indicative of a lack of psychological detachment from professionals’ work environments when entering the home domain. This lack of segmentation poses a threat to the quality of family life and well-being (Park et al., 2011). Establishing a segmentation norm in workgroups by managers and supervisors would be helpful in improving construction professionals’ work-family boundary management (Park et al., 2011).

The relationship between role blurring and work-to-family conflict

Pre-occupation with work, multi-tasking, and after-hours work contact were each positively associated with work-to-family conflict. Thus, role blurring activities encroach on family roles and occupy the time and energy that construction professionals could otherwise spend on family responsibilities. The finding supports Voydanoff (2005) that role blurring is a form of boundary-spanning demands which add to work-to-family conflict.

Work pressure was also directly positively associated with construction professionals’ experience of work-to-family conflict (not hypothesised *a priori*). Work pressure influences work-to-family conflict both directly and indirectly via its direct positive associations with each of work contact, multi-tasking, and pre-occupation with work whilst at home. Our findings extend previous research examining the relationship between work pressure and work-to-family conflict by identifying different pathways and revealing the underlying mechanism (e.g., through role blurring activities). Hypothesis H7, H8, and H9 are therefore supported.

The positive associations between work demands, role blurring activities and work-to-family conflict suggest that construction organisations should adopt an appropriate work design characterized by



manageable workloads and reasonable work hours to protect employees from the harm of work-to-family conflict. Employees are more likely to be productive and deliver construction projects on time if they live a balanced and healthy lifestyle with reduced stress of juggling between work and family commitments (Francis et al., 2013). The negative impact of work demands and role blurring on work-to-family conflict suggests the construction industry need to confront the current working culture by providing targeted support to facilitate employees in better managing work and family interface.

The consequence of work-to-family conflict

Positive associations were found between work-to-family conflict and each of depression and sleep problems, and between depression and sleep problems, consistent with previous studies that have reported significant relationships between work-to-family conflict and mental health issues and sleep irregularities (Bowen et al., 2018; Hämmig et al., 2009; Schieman & Young, 2013). The findings also support McTernan et al.'s (2016) assertion that work-to-family conflict produces stress in an individual, potentially leading to psychological strain-related outcomes such as depressive symptoms and sleep disorders. Hypotheses H10, H11, and H12 are therefore supported.

A direct positive association between pre-occupation with work whilst at home and sleep problems experienced by construction professionals (not hypothesised *a priori*) was noted. This finding is in line with the longitudinal study conducted by Åkerstedt et al. (2012), who reported that work pre-occupation is a strong predictor of subsequent sleep impairment and that increased work pre-occupation is related to new cases of impaired sleep.

This study noted a positive association between alcohol consumption and sleep problems. However, contrary to expectations, alcohol use was negatively associated with depression. A possible explanation for this unexpected finding may be explained by Peltzer and Pengpid (2015) who found a reverse U-shaped association between alcohol use volume and frequency, and depressive symptoms. In essence, it may not be appropriate to hypothesize a linear causal relationship between depression and alcohol consumption (as we have in this study). Hypothesis H13 was therefore not supported, but Hypothesis 14 was supported.

The positive associations between work pressure and work-to-family conflict, between work-to-family conflict and depression, and between depression and sleep irregularities are cause for concern, underscoring the harmful effects of work pressure on family relationships and the health of individual construction professionals. The link between sleep problems and alcohol use is an exacerbating factor. Companies should consider providing wellness and stress management programs to employees so that employees may better cope with stress arising from work-family conflict.

LIMITATIONS

The survey research was limited by the self-reporting method it used. Although self-reporting measures are not in themselves problematic, it is necessary to continuously assess their validity by measuring their association with other established indicators of the same measures (concurrent/criterion validity).

This study has only examined one direction of work-family conflict i.e., work-to-family conflict, but not family-to-work conflict. It is acknowledged that construction professionals' personal circumstances and family structure features may have an impact on their work-life. For example, construction professionals who have young children at home or are the main carers of the family would probably be contacted to deal with family matters (e.g., calling schools, making doctor's appointments) whilst at work. It is suggested that future research also examine the direction of family-to-work conflict and explore relevant determinants.



CONCLUSION

This study contributes to the body of knowledge by providing empirical evidence regarding the links between work demands, work-to-family conflict, and deterioration of health and well-being experienced by construction professionals. In addition, the study has further explored how work conditions reshape work-family boundaries through role blurring. It further adds to the body of knowledge by demonstrating how the work domain interferes with the family domain through the boundary permeating mechanism of role blurring activities. The research provides useful pointers to construction employers i.e., they should carefully manage work demands so that employees are able to reduce the stress emanating from juggling between work and life commitments, live a balanced lifestyle, maintain health and well-being, and ultimately remain productive at work. The relationship between depression and alcohol consumption identified in this study is different from that reported in most previous research. Further research is needed to examine the complex relationship between depression and alcohol consumption in depth.

The research highlights the importance of an appropriate work design with reasonable workloads and work hours in the construction industry, as well as the establishment of a segmentation norm in the workplace to reduce the work-family role conflict experienced by many construction professionals.

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Data-driven Analysis of the Impact of Occupants' Preference on Building Performance in Classroom Spaces

Ayca Duran, Ipek Gursel Dino

Middle East Technical University, Turkey

Correspondence: aycad@metu.edu.tr

Abstract

Occupant behavior is a prominent factor affecting occupants' well-being indoors. Occupants' thermal satisfaction is subjective, as the sensation of comfort is subjective and depends on physiological factors. Variations in the occupants' thermal preferences have a significant impact on building performance and occupant's comfort. However, occupants' behavior and preferences are standardized in building simulations with generalized assumptions on comfort conditions. For this reason, their influence on the building performance and occupants' desired comfort conditions are neglected. Particularly, educational buildings should provide their occupants' satisfactory indoor environments as indoor conditions play a determinant role in the performance, productivity, attendance, and health of both students and teachers. Classrooms generally operate at full capacity, leading to high internal gains, severe indoor overheating, and increased carbon dioxide concentration levels if not adequately ventilated. This study presents a data-driven methodology to analyze the impact of occupants' preferences on their comfort in classroom spaces and its environmental impact. Based on the simulation outputs, three prediction models with different decision tree (DT) algorithms (Classification and Regression Trees, Random Forest, and Extreme Gradient Boosting) are build and compared. In order to understand relationships between input features and outputs, in other words, occupant-controlled building parameters' effect on well-being in classrooms and the environmental impact, DT feature importance's are calculated. There is a tradeoff between resource consumption and occupant comfort and well-being should be maintained in school buildings, especially in classrooms. In this study, occupant well-being in classroom spaces is related to thermal comfort and indoor air quality. A naturally ventilated classroom space facing south in Ankara, Turkey, is selected as a case study.

Keywords: Building energy performance, data-driven model, educational building, occupant behavior.

INTRODUCTION

Occupant behavior has been one of the most indicative factors in building performance. People spend a great amount of time indoors. Meanwhile, they interact with the buildings to maintain optimal indoor thermal comfort conditions. This interaction has a noticeable impact on building energy use and indoor environmental quality during the building's operational period. Therefore, in recent decades, occupant behavior and its effect on energy use and thermal comfort have gained increasing interest (Hong, Taylor-Lange, D'Oca, Yan, & Corgnati, 2016).

Although building occupants have control over the building operations to maintain their thermal comfort, the sensation of comfort is not necessarily the same for each individual. According to Fanger's well-known equation, thermal comfort is associated with six drivers; metabolic rate, clothing insulation, air temperature, radiant temperature, relative humidity, and air velocity (Fanger, 1970). Two of the determinants, clothing insulation and metabolic rate, vary from one individual to another. The latter depends on individuals' characteristics of gender, age, weight, activity, etc.; therefore, it has a tremendous impact on the subjective perception of thermal sensation and comfort (Luoab, et al., 2018). This variety in the feeling of comfort indoors can be expressed as the tolerance to the indoor



environmental conditions. Some studies reveal that predicted uncomfortable conditions satisfy some users due to the variety in the comfort sensation. For instance, school children in classrooms are satisfied with lower temperatures than those predicted by adaptive temperature models (ter Mors, Hensen, Loomans, & Boerstra, 2011; de Dear, Kim, Candido, & Deuble, 2015) and some occupants' preferences are not in comfort ranges provided in standards (Zomorodian, Tahsildoosta, & Hafezi, 2016). Therefore, generalized assumptions on building controls may not be valid to offer comfortable and healthy indoor spaces, and occupant tolerances can play an essential role in the comfort and environmental impact of buildings.

Likewise, children spend around 85% of their time indoors (Klepeis, et al., 2001) and most of them spend more time at school than any other place but at home until the age of 18 (Bluyssen, Zhang, Kurvers, Overtoom, & Ortiz-Sanchez, 2018). Performance, productivity, attendance, and health of both students and teachers depend considerably on the indoor conditions (Zomorodian, Tahsildoosta, & Hafezi, 2016). A study based on a survey and observations on test scores implies that an increase in satisfaction with the indoor environmental quality improves the students learning performance (Mumovic, et al., 2009). This sensitivity to indoor climate conditions could be related to the nature of children's anatomical structure. Children are more susceptible to certain environmental pollutants than adults, as the amount of air intake proportional to their body weight is more significant (Faustman, Silbernagel, Burbacher, & Ponce, 2000). Therefore, their well-being in classroom spaces is critical.

Indoor environmental quality influences the well-being in school buildings (Faustman, Silbernagel, Burbacher, & Ponce, 2000). As two major determinant factors of healthy classrooms, indoor air quality and thermal comfort are widely emphasized in many studies on educational facilities (Zomorodian, Tahsildoosta, & Hafezi, 2016). In classrooms, the connection between occupant-centric controls and these two well-being indicators are analyzed in this study. First, well-being in classrooms considerably relies on indoor air quality through CO₂ concentration. It is also recommended by ASHRAE Standard 62 (ASHRAE, 2019) and STM D6245 (ASTM, 1998), and evaluation of ventilation of a room due to CO₂ generated by its occupants becomes a standard tool (Bartlett, Martinez, & Bert, 2004). Several studies have found an inverse correlation between the CO₂ concentration levels and pupils' annual school attendance (Gaihre, Semple, Miller, Fielding, & Turner, 2014; Shendell, et al., 2004). Similarly, it is found that students' performance in math exams is also significantly related to classroom-level ventilation concerning CO₂ concentrations (Shaughnessy, Nevalainen, & Moschandreas, 2006). Additionally, the link between indoor air and thermal quality is a prominent study subject in the field (Fabi, Andersen, & Corgnati, 2013). As the second important factor, occupants' thermal comfort is studied for healthy classroom spaces since thermal comfort affects students' performance. Air temperature, one of the factors influencing thermal comfort, has a considerable impact on learning (Heschong Mahone Group, 2003). The thermal sensation is subjective, and some studies indicate that pupils prefer cooler environments. Hence, thermal comfort perception is one of the critical reasons for occupants to interact with building controls such as adjusting set-points or opening windows (Schweiker, Carlucci, Andersen, Dong, & O'Brien, 2018) which affects both CO₂ concentration and thermal comfort. However, there is a tradeoff between comfort and environmental impact. The majority of the energy consumption is reasoned for thermal comfort indoors (Yang, Yan, & Lam, 2014). Similarly, for fresh air intake in naturally ventilated spaces, window opening activity implies a considerable energy loss and an increase in resource consumption. As a critical indicator of environmental impact, the heating energy consumption of a naturally ventilated space is calculated.

Since buildings consume a significant amount of energy and people spent a tremendous amount of their time indoors, building performance improvement is crucial. In this regard, building performance forecasting gains importance. In the literature, two main approaches are widely adopted. While the first method relies on physical models, the second employs statistical techniques, including machine learning (ML) methods (Foucquier, Robert, Suard, Stéphan, & Jay, 2013). Especially when various building parameters are involved and affect the performance indicators, ML tools are trusted broadly



by researchers (Tsanas & Xifara, 2012). Tree-based methods have been one of the most important supervised ML methods (Friedman, Hastie, & Tibshirani, 2009) and are commonly used in the area of building performance prediction (Amasyali & El-Gohary, 2018). A combination of physical models and statistical techniques is widely used to overcome the limitations of both when several design alternatives are needed to be evaluated. In this study, a hybrid approach is employed to provide a methodology to explore the relationship between inputs (occupant-centric controls) and outputs (performance indicators) based on the simulation data.

Current literature focuses on occupant preferences in data-driven building performance prediction, amongst other building parameters. Kim et al. developed a linear regression model to find the correlation between occupancy and electricity consumption (Kim & Srebric, 2017). Yang et al. proposed a multi-agent system for realizing user-centered control of buildings (Yang & Wang, 2013). Paudel et al. developed dynamic ANNs focusing on building occupancy profiles to predict heating energy consumption (Paudel, Elmtiri, Kling, Le Corre, & Lacarrière, 2014). Various occupancy densities, among other parameters, were considered in an ANN model to optimize HVAC thermal energy storage by Ben-Nakhi (Ben-Nakhi & Mahmoud, 2004). However, to our knowledge, no research particularly focuses on occupancy profiles in educational buildings using ML models.

Although many data-driven studies focus on CO₂ concentration levels and thermal comfort in classroom spaces, a comparative data-driven analysis based on occupants' preferences on several major occupant-centric controls and these decisions impact occupant well-being and building performance is hitherto unaddressed. Therefore, this study presents a data-driven method to evaluate several different occupant decision scenarios and their effects on the selected comfort indicators. The generated data is further analyzed to understand the sensitivity of the indicators to the given input parameters. The presented methodology can be applied to evaluate various design parameter's relation to building performance indicators.

METHODOLOGY

This study presents a data-driven methodology that can evaluate the influence of occupant preferences on building performance. The data-driven methodology is tested on three prediction models based on different DT algorithms varying in complexity. DTs are one of the important methods of supervised ML techniques used for building performance prediction (Amasyali & El-Gohary, 2018). DTs are more robust when outliers or faulty data points exist in the dataset than other methods such as k-nearest neighbor or other nonparametric methods (Breiman, Jerome, Stone, & Olshen, 1984). In addition, the implementation of DTs is advantageous in terms of comprehensibility over "black-box" models such as neural networks (Kotsiantis, 2013). Hence, DTs are selected for this study, and three DT algorithms with varying complexities are tested to find the most suitable DT method for formulated problems.

Data for prediction model training and testing is generated using building energy simulations. A south-facing, naturally ventilated classroom in Ankara, Turkey, is modeled and simulated using EnergyPlus engine Ladybug Tools (Roudsari & Pak, 2013). After data preprocessing and exploration, the performance of the decision tree prediction models is evaluated, and the importance of input features for specified outputs is calculated. ML models are built with Python programming language and sci-kit learn library (Pedregosa, et al., 2011). The described methodology () also evaluates the input's relative importance on the performance indicators.

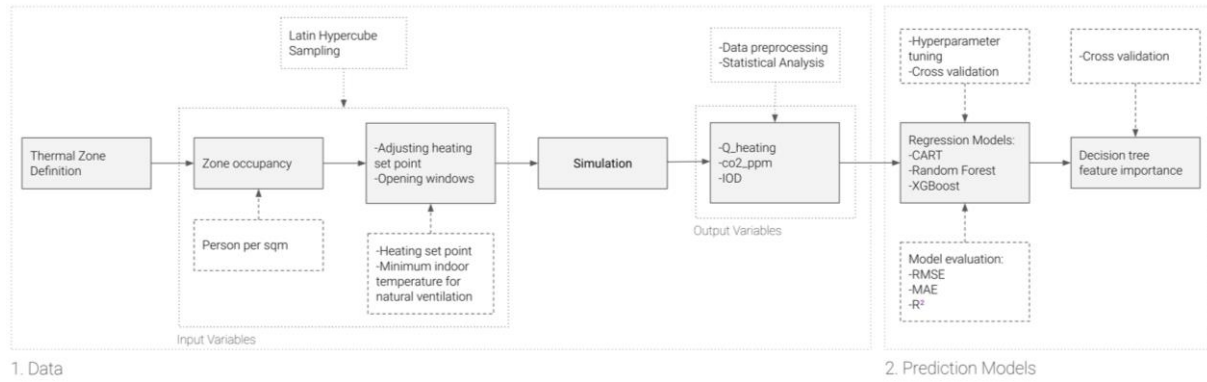


Figure 11: The proposed analysis approach

Data

Thermal zone definition

A single south-facing classroom on the middle floor of a three-story school building is modeled. The classroom is 8 m long, 6 m wide and, 3.2 m high. Material properties and zone loads are set according to an existing and previously studied building (Akkose, Akgul, & Dino, 2021). Standard classroom occupant capacity is set to 24 students by the school (0.53 ppl/m²), and the classroom is occupied between 08:00 and 17:00 during weekdays from the beginning of September to the end of June.

Variables and sampling

The occupant-controlled parameters that have the highest impact on classrooms are selected as input variables (Table 14). Latin Hypercube Sampling (LHS) method was used to generate 400 data points for possible preference scenarios. Due to its effective capacity for stratification, LHS can deal with high levels of uncertainty and can quantify parameter sensitivity with relatively small sample sizes (Helton, Johnson, Sallaberry, & Storlie, 2006). LHS is also reported to perform well when computationally demanding prediction models are being tested.

Mathematical representation	Input variable	Unit	Distribution	Range	Increment	Sampling
X1	Occupant number	ppl	uniform	$\in \mathbb{R}: (10 - 26)$	0.04	LHS
X2	T_{heat}	°C	uniform	$\in \mathbb{R}: (19 - 23)$	0.0075	LHS
X3	$T_{\text{min_vent}}$	°C	uniform	$\in \mathbb{R}: (23 - 26)$	0.01	LHS
X4	Operable glazing area	unitless	uniform	$\in \mathbb{R}: (0.1 - 0.9)$	0.002	LHS

Table 14: Within the given ranges, 400 data points are sampled for each input variable.

The most typical means of cooling and maintaining indoor air quality is natural ventilation through windows (D'Oca & Hong, 2014). This activity is primarily dependent on indoor and outdoor temperatures (Rijal, et al., 2007). Since minimum indoor temperature ($T_{\text{min_vent}}$) is one of the determinants for the window opening decision for naturally ventilated spaces in simulation tools and occupants sense the changes in indoor air temperature, $T_{\text{min_vent}}$ is selected as the decision-making reason. Operable window area, related to window opening decision, also significantly impacts natural ventilation since the airflow rate is affected by the size of openings (Santamouris, et al., 2008). It is generally decided by school management and included as an occupant-controlled driver. Studies show that the CO₂ concentration in classrooms is significantly related to the number of pupils sharing the same room (Yalçın, Balta, & Özmen, 2018). Since it is also a factor related to the occupants and their existence, number of students vary in the generated occupation scenarios. Lastly, the heating set-point (T_{heat}), a fundamental way to control indoor air temperature, is selected as another input variable. Research on space heating preferences in social housing reveals that preferred T_{heat} varies significantly (Bruce-Konuah, Jones, Fuertes, & de Wilde, 2019).

The output variables are annual heating energy demand (kWh/m^2), indoor CO_2 exceedance (ppm), and indoor overheating degree ($^{\circ}\text{C}$) (only during the occupied hours). Annual heating energy demand normalized by floor area (Q_H) is recorded as the first output. Indoor overheating degree (IOD) (Hamdy, Carlucci, Hoes, & Hensen, 2017) is quantified by the difference between indoor temperatures and the indoor operative temperature limit of 28°C . The sum of these hourly differences constitutes IOD. With a similar approach, indoor CO_2 exceedance is calculated to understand the intensity and frequency of concentration levels above the threshold. The outdoor CO_2 concentration is assumed to be 300 parts per million (ppm); therefore, with respect to ASHRAE standards, the highest acceptable CO_2 concentration limit is selected as 1000 ppm (ASHRAE, 2019). Concentrations above this threshold are counted for each occupied hour.

Data preprocessing and statistical analysis

400 simulations were performed. Data points that are detected as outliers and represent unlikely preference scenarios are eliminated from the dataset. Following, the Shapiro-Wilk normality test has been conducted ($\alpha = 0.05$) to check if the data is normally distributed. A correlation matrix is generated to capture variable dependency. The Spearman correlation coefficient (ρ) is calculated to evaluate the monotonic relationship between variables. The p-value is calculated with the significance level of 0.05 to determine the significance of these relationships, where the correlation of variables is statistically significant when the p-value < 0.05 .

Prediction models

Various ML techniques have been used to predict building performance, including multiple linear regression, artificial neural networks, decision trees (DTs), and support vector machines (Seyedzadeh, Rahimian, Glesk, & Roper, 2018). DTs are one of the most powerful supervised learning methods and are widely used in building performance prediction. In this study, three DT methods, two of which are most commonly used in building performance studies, namely Classification and Regression Trees (CART) and Random Forests (RF), together with a recent technique, Extreme Gradient Boosting (XGBoost), are used and tested (Amasyali & El-Gohary, 2018). The selected algorithms' complexity varies as described below.

The complete and preprocessed dataset is split into training, validation, and test subsets. The proportion of data used for training to validation and test datasets is specified as 8/2 after performance comparisons with 9/1, 7/3, and 6/4. After splitting, with the same training, validation, and test subsets, three following DT prediction models are built:

CART (Breiman, Jerome, Stone, & Olshen, 1984): In CART, the input feature space is recursively split into smaller groups with increasing levels of homogeneity in their outputs. The tree grows until there is no need for a further split when a criterion is met. In order to control tree complexity, the choice of the criteria is critical. This process starts with the complete set of observations at the root node, and splitting continues until there is no need for a split, in other words, reached to the leaves.

RF (Breiman, Random Forests, 2001): RF is an ensemble model combining predictions of many regression trees (CART). Instead of relying on a single tree, as in CART, the RF predictions are based on a set of trees. As a result, it yields more robust and stable results than CART. In order to grow multiple trees, bootstrap samples and randomness are used in prediction. A randomly selected subset of variables with the same size as the training data is transferred into an algorithm similar to CART. A forest of different trees, in other words, an ensemble of trees, is formed. For regression, each tree's prediction is averaged.

XGBoost (Chen & Guestrin, 2016): XGBoost is a scalable tree boosting system that provides state-of-art results. In RF, individual trees are grown unaware of each other. However, with the boosting method, trees are grown depending on the results of previously built trees. Conceptually, the aim is to improve the performance of each new tree by learning from the mistakes of its predecessors. When

growing trees, random subsampling is utilized at the individual split points. XGBoost provides a scalable boosting implementation with efficient parallelization.

Hyperparameter tuning

Different prediction model hyperparameters are required to be tuned for the tested DTs. For CART, stopping criteria such as the minimum number of observations at each leaf and the maximum depth of the tree is critical. For the RF and XGBoost, other parameters such as learning rate, subsample size, or gamma also become determinants of model performance. For this reason, a grid of hyperparameters is tested with a grid-search method accompanied by cross-validation (CV) to build the best prediction models with the optimized hyperparameters. Following, to robustly estimate the performance of each technique, a widely used 10-fold CV method is employed (Kohavi, 1995), and prediction model evaluation results were based on the CV results.

Model evaluation

For prediction model evaluation, root mean square error (RMSE), mean squared error (MSE), and R-squared (R^2) is calculated (2), (3), (4).

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (p_i - a_i)^2}{n}} \quad (2)$$

$$MSE = \frac{1}{n} \sum_{i=1}^n (p_i - a_i)^2 \quad (3)$$

$$R^2 = 1 - \frac{\sum_{i=1}^n (p_i - a_i)^2}{\sum_{i=1}^n (p_i - \bar{a}_i)^2} \quad (4)$$

where p_i is the predicted value of the performance indicator, a_i is the actual value of the indicator and n is the number of data points in the dataset.

Variable importance

Feature importance provides an understanding of variables' interaction that offers predictive accuracy. An existing method (Breiman, Random Forests, 2001) is used to calculate feature importance. Permuting the input variables, an increase in accuracy is calculated, and the relative importance of each variable is derived. It gives insight into the performance of the model with respect to the input's interaction.

RESULTS

Data analysis

Six data points were removed from the dataset since they were in the highest decile for y_1 and detected as outliers (Figure 12). They had common properties such that the X_2 is close to the upper limit of the observation range while X_3 is close to the minimum value in the given interval. In other words, in these scenarios, the indoor temperature which aimed to maintain steady is slightly lower

Variables	Units	Mean	Std.	Min	Max	p-value
y_1	kWh/m ²	9.6578	5.761	3.9693	33.143	0.0000
y_2	ppm	1402878	27993.309	607479.6	2243508	0.0000
y_3	°C	171.534	356.674	28.187	714.822	0.0000

Table 15: Data description.

than the indoor temperature that allows window opening activity; therefore, there is a constant energy loss, and the classroom remains heated.

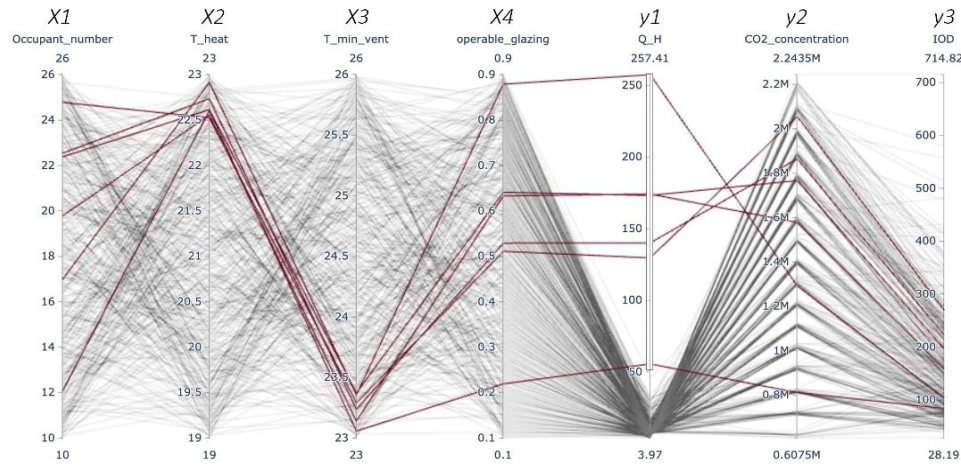


Figure 12: Variables and outliers.

The statistical description of the output variables and Shapiro-Wilk normality test results can be found in Table 15. Since $p\text{-value} < 0.05$ is proven to be non-normal distribution, none of the variables follows the normal distribution. The p and $p\text{-values}$ can be found in Figure 13 and Table 16, respectively. No significant correlation between input variables is observed. Notably, there is a perfect positive relationship between the $X1$ and $y2$ with $\rho = 1$. The proportional relationship between $X1$ and $y3$ and also $X2$ and $y1$ are statistically significant. Additionally, output variables $y2$ and $y3$ have a positive correlation. It should be noted that $X1$ and $y1$, likewise $X4$ and $y3$, have moderate negative correlations, which are significant.

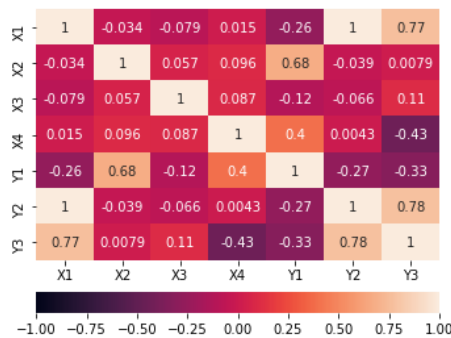


Figure 13: Spearman correlation coefficient results.

	p-value						
	X1	X2	X3	X4	y1	y2	y3
X1	0.0	0.498	0.12	0.771	0.000	0.0	0.000
X2	0.498	0.0	0.261	0.057	0.000	0.444	0.877
X3	0.12	0.261	0.0	0.086	0.023	0.190	0.033
X4	0.771	0.057	0.086	0.0	0.000	0.933	0.000
y1	0.000	0.000	0.000	0.000	0.0	0.000	0.000
y2	0.0	0.444	0.190	0.933	0.000	0.0	0.000
y3	0.000	0.877	0.033	0.000	0.000	0.000	0.0

Table 16: p-values for Spearman correlation.

bold: $p\text{-value} < 0.05$.

Model performances and variable importance

XGBoost outperforms among the tested ML algorithms in predicting all three output variables (Table 17). Since there is a strong proportional relationship between $X1$ and $y2$, all models performed well in predicting $y2$. However, XGBoost and RF models are required to be simplified to avoid overfitting problems. Additionally, XGBoost, the most successful model for predicting $y1$ and $y3$, results in the RMSE of 0.964 kWh/m² and 8.463 °C, corresponding to the average prediction error of 10% and 5%, respectively. CART underperforms compared to the RF and XGBoost except for predicting $y2$.

Since input variables are not correlated, it can be said that $X1$ has been the most predictive variable for both $y2$ and $y3$, while for $y1$, the importance of $X2$ and $X4$ dominate other variables (Table 18). An increase in the model complexity implies an increase in the importance of variables that do not directly affect prediction performance. For instance, while predicting $y1$ in the simplest model, CART, $X1$ accounts for 57% of predictability. On the other hand, it is only 45% in the best-performing XGBoost model. It can be said that the difference is distributed to the other variables since the importance of $X1$, $X3$, and $X4$ is increases. However, this may give rise to an overfitting problem; therefore, a balance between bias and variance should be maintained.

Model	Output Variables	Performance Evaluation Metric		
		R ²	RMSE	MSE
CART	y1	0.945	1.330	1.769
	y2	1	6629.555	43950996.704
	y3	0.872	29.996	897.932
RF	y1	0.960	1.129	1.274
	y2	1	8576.383	73554350.022
	y3	0.970	14.446	208.684
XGBoost	y1	0.971	0.964	0.930
	y2	0.999	14186.172	201247468.952
	y3	0.990	8.463	71.617

Table 17: Prediction performances based on R², RMSE, and MSE.

Implications on occupant well-being and building performance

High CO₂ concentrations occur mainly because of the increase in number of students. But it should be noted that there is also a low inverse correlation which is significant ($\alpha = 0.05$) between CO₂ levels and Q_H. IOD, the second performance indicator selected in this study affecting well-being in classrooms, is also positively correlated with the number of occupants. While an increase in the number of students implies higher IOD, an increase in operable glazing area prevents it. On the other hand, Q_H has a very low dependence on the number of occupants. It is correlated with the T_{heat} mainly and also, and it has a moderate positive correlation with the operable glazing area.

In conclusion, among the selected input parameters, the occupant number in classrooms was found to be the most impactful parameter on healthy indoors regarding the chosen objectives. Operable glazing area and T_{min_vent} are the following drivers of the studied comfort indicators. Although, T_{heat} is the most impactful determinant of Q_H, which influences occupant's comfort and well-being during the heating period, its effect on the selected comfort indicators is observed to be minor compared to other variables.

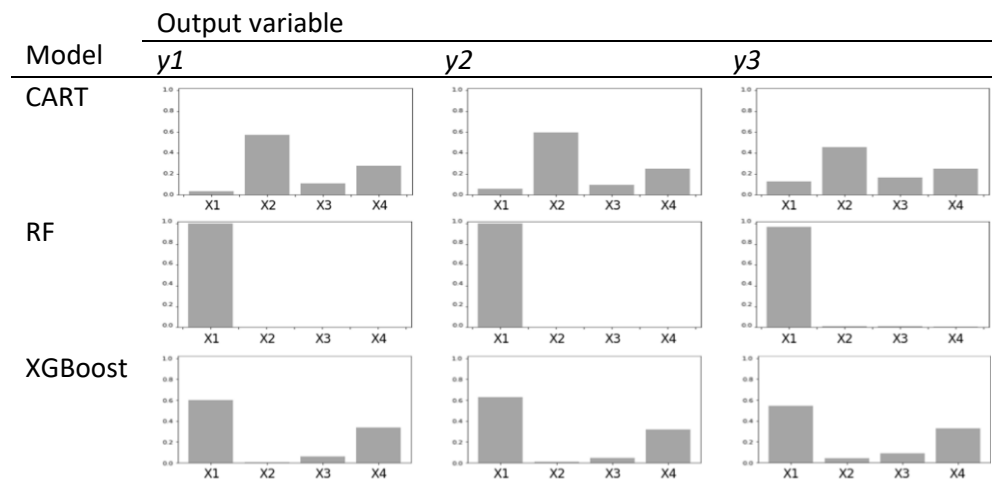


Table 18: Feature importance results.

DISCUSSION AND CONCLUSION

We have applied a data-driven methodology where the performance of classroom space is predicted with four occupant-centric controls. After statistical exploration of the data, we predicted selected output variables with three different DT-based ML models. The findings of this study agree with the success of the XGBoost model, which provides superior results for complex problems. However, when the problem is simple, likewise the prediction of CO₂ concentration, overfitting problem should be



prevented. Although performance metrics indicate satisfactory results for prediction models, especially for XGBoost, there is room for improvement with a more expansive search space of hyperparameters. XGBoost can be preferred in more difficult prediction problems amongst the methods we tested for an increased number of input variables and various other performance indicators as outputs. Since the accuracy of prediction results is satisfactory, such DT-based methods can be reliably used for fast and easy prediction of building performance. Tested methods can also be combined with optimization-based workflows for the performance prediction of large volumes of building design choices. In this study, we focused on several main occupant preferences and their impact on selected performance indicators. Several other occupant preferences, such as when to pull blinds down or turn lights on, can be included in the parameter space for future research.

Moreover, variable importance is generally calculated for feature selection iteratively. When there is collinearity between input variables, the interpretation of variable importance results may be misleading; therefore, the data analysis section of the applied method is critical. We have not detected any collinearity in this study, and our interpretations are based on this result. The statistical analysis gives an important insight into selected parameters and their relationship with the performance indicators together with feature importance analysis. IOD depends significantly on the number of students and operable glazing area. Ventilation has been reported to be an effective measure to combat overheating in the existing literature (Bluyssen, Zhang, Kurvers, Overtoom, & Ortiz-Sanchez, 2018). Although we have not included air flow rate, its correlation with operable glazing area reported in existing literature (Santamouris, et al., 2008) coincides with the importance of operable glazing area. In contrast, its relative importance to occupant number is explored in this study. For air quality, occupant density is the most dominant factor in parallel to findings of previous studies (Yalçın, Balta, & Özmen, 2018). On the other hand, while T_{\min_vent} has a minor impact, T_{heat} has a negligible impact compared to the other two input variables for IOD. The significance of T_{heat} on Q_H conforms to studies pointing to lowering T_{heat} for considerable energy savings (Hoyt, Arens, & Zhang, 2015).

Based on the generated preference scenarios, it is possible to minimize IOD to the annual excess amount of only 28.2 °C. Concordantly, CO₂ concentration levels above the limit of 1000 ppm can be minimized to 1256 ppm for occupied hours on average. In terms of IOD, the best performing scenarios have the number of students minimized to 10-11, the maximum operable glazing area close to 0.9, and T_{\min_vent} around the low bound of the interval. In other words, less heat gain from occupants coupled with more allowance of fresh air in relatively lower temperatures and increased operable glazing area can improve well-being in classroom spaces.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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The Home as a Work-life Hub: A Policy (and Design) Blackspot

Kirsten Day, Andrew Martel

University of Melbourne, Australia

Correspondence: dayk@unimelb.edu.au

ABSTRACT

There is a complex relationship between home and work for people with a disability that is not reflected in the many policies and legislative frameworks that apply to housing in Australia. These include Commonwealth housing policy (largely financial in nature), the Building Code of Australia, and Home Modification Schemes run through the National Disability Insurance Scheme. Much current policy settings assume housing as a passive economic generator – a financial asset that appreciates and gains value over time.

However, for many people with disability, the home is a place of active economic activity, both by the person with disability (working from home) and for them, as external workers come into the home to provide services that support their activities of daily life. This complicates the spaces within dwellings, particularly in terms of public and private space, which effects personal and professional places. The policy and legislative disconnect is reflected in housing design which manifests in a structural inequality – homes are not accessible, and a social inequality – homes do not support work or socializing.

This paper reviews the policy and legislation used to support appropriate design recognising the role of the home as a location that blends elements of privacy, work, and socialising, while also providing the physical support so people can work and socialize in the community as full citizens. The aim of the ongoing research is to show how change and innovation to the legislative frameworks and the role that AECM consultants can play in improving the wellbeing of people who live with disability.

KEYWORDS building codes, disability, policy, legislative frameworks, housing

INTRODUCTION

The home is a complex space for many people with a disability. For most people, a home is a place of rest, rejuvenation, eating, talking, and relaxing. However, many people with a disability will spend a larger amount of time inside the home than is typical (Deane et al., 2009; Mencap, 2016). Often this reflects social conditions, including lower levels of employment and study (ABS, 2018), or physical conditions such as the ability to easily enter or exit a home through doorways not designed to accommodate people with physical disabilities (Australian Institute of Health and Welfare, 2020). Depending on the level of assistance needed, what might be traditionally considered the most private of spaces of a home—bedrooms, bathrooms, and toilets—can be the most public. The function of those spaces may be transformed from ones of privacy into workspaces open to strangers. For people living with a disability, home is often also the workplace, as people with a disability are over-represented as home-based entrepreneurs running small businesses (Darcy et al., 2020). However, for many people, particularly where a disability affects the ability to perform ‘activities of everyday life’ (ADL), the home is also a place where an outside workforce—such as at-home support workers—are a regular presence. The nature of at-home support work in supporting ADL, such as assistance in dressing, bathing, and toileting, inverts the notion of private and public spaces in the home, of the



personal and the professional. The home is also a place of work. Therefore, examining the nexus of disability and work through a prism, in terms of people working at and in the home, might allow for broader conversations for all people working from home to be had.

The home as a place of work will be familiar, particularly in a COVID normal world where a rapid change to working from home was imposed on many (Boland et al., 2020). For those who share homes with others, the makeshift office on the kitchen table and the negotiation of workspace and communication space with others revealed that the space where we dwell is often not equipped for multi purposes beyond rest, rejuvenation, and eating. However, despite renewed debate about working from home, and the economic and social consequences that might entail, there has been little debate on the legislative environment that regulates home building in Australia.

This paper conducts a systematic review of existing policy documents including building codes, design guidelines, and criteria for funding assistance for people with a disability, revealing that these documents are almost completely silent on the issue of work and home. Notions of safety, accessibility and amenity provisions that are commonplace and mandatory for designated workplaces are absent from regulations that govern private dwellings. Current housing policies in Australia do little to support the needs of people with a disability, or the population more generally, to negotiate a more complex notion of home.

LITERATURE REVIEW

Australian Government Housing Policy

Australia is a federated nation with responsibilities split between the National (Commonwealth) Government and those of the States and Territories. Housing has traditionally been a responsibility of State Governments, while taxation is largely the preserve of the Commonwealth. Consequently, Commonwealth Government housing policy is largely demand-side driven and utilises monetary incentives to influence market behaviour. The effect of two related tax policy initiatives, negative gearing, and the capital gains offset, have significantly influenced the market proportion of investors versus 'owner-occupiers'.

Negative gearing refers to the ability of an investor to deduct losses from an investment (including payment of interest on a loan) from their primary tax bill. The capital gains offset effectively halved the amount of capital gains tax due (from 30 to 15%) from the sale of an investment (Duncan et al., 2018). The combination of the two policies incentives investors to compete for housing stock with people who wish to buy a house to live in. For (potential) owner-occupiers, first home buyer's schemes, in various forms, are supported by both the Commonwealth's First Home Loan Deposit Scheme (NHFIC, 2021) and individual States (such as Victoria's First Home Owner Grants (State Revenue Office, 2021)). These schemes offer a momentary grant to assist first home buyers to enter the housing market. Similar in form, the Commonwealth has introduced the 'Homebuilder' scheme as a post-COVID-19 stimulus that offered a grant to an existing homeowner (including first home buyers) to contribute to the building of a new home, or a substantial home renovation, subject to a series of criteria (Australian Government, 2021; State Revenue Office, 2021).

On the supply side, there are no large-scale financial incentives at the Commonwealth level to construct new dwellings, although post-COVID-19 several States introduced significant new spending on social housing (see Victoria's Big Housing Build (State Government of Victoria, 2021)). Government influence here is largely directed through regulation, primarily via the National Construction Code (2019a) (NCC), which is overseen at a national level by the Australian Building Codes Board (ABCB). The NCC in part consists of the Building Code of Australia (BCA), a performance-based code that



regulates construction standards (Commonwealth of Australia and the States and Territories, 2019a). Based on the London Building Act, the code was first introduced to Australia in 1810, with an emphasis on safety (especially fire), health (fresh air and sunlight access), and community expectations around how buildings should perform to support activities carried out in them (Building Connection, 2011).

Concerns around the appropriateness of buildings for people with a disability are largely absent from the BCA, but in response to national legislation, the Disability Discrimination Act 1992 (Federal Register of Legislation, 1993) new legislation, the Access to Premises Act, and associated Disability (Access to Premises - Buildings) Standards (2010) were introduced. These standards, however, do not apply to residential dwellings, only public and commercial buildings.

Although national, the NCC is enforced via State-based legislation and associated statutory authorities, as are local planning and land-use regulations. In addition to the federal codes, most Australian States have local design guidelines (predominantly for apartments). In Victoria, for example, the Better Apartment Design Standards (BADS) (Victoria & Department of Environment, 2021) and in New South Wales, the State Environment Planning Policy No. 65 - Design Quality in Residential Apartment Development (SEPP 65) (2015). SEPP 65's design quality principles include: context and neighbourhood character, built form and scale, density, sustainability, landscape, amenity, safety, housing diversity and social interaction, and aesthetics.

Housing and the Disability Sector in Australia

Australia's housing programs for people with a disability have historically been extremely fragmented. Each State operated its own system, with the provision of housing divided between State Government Departments, independent but government backed entities (such as the Traffic Accident Commission), and not-for-profit community organisations. The most common housing typology was large group homes, which combined housing with service support and medical needs (Bigby & Bould, 2017). Beginning in 2013, the National Disability Insurance Scheme (NDIS) was to supersede the various State programs and coordinate a national approach to providing the necessary support for people with a disability based on individual needs. The NDIS is a needs-based funding model to allow people with a disability more agency over the provision of their support, and that it is not a housing scheme, stating that it supports people living wherever they choose in the community and enabling service support to come to them (Bonyhady, 2014).

However, there are two areas of the NDIS that concern direct housing support. The Specialist Disability Accommodation (SDA) scheme was initiated as part of the NDIS as a recognition that some participants (as the NDIS refers to people with a disability who are part of the scheme) will have needs such that it is not possible to separate their living arrangements from their support requirements. Initially, the SDA was estimated to apply to around 6% of NDIS participants (Beer et al., 2019), providing a separate body of funds to the participant to use towards housing needs (buying or renting) from a property approved by the NDIS. The NDIS's expectation is that the private sector will supply new, specialized housing stock, incentivized by a funding model that provided higher than average return on investment than for standard market-based houses and apartments (Beer et al., 2019). The NDIS designated four categories of SDA design: improved liveability, robust, fully accessible, and high physical support. The design criteria differs across the categories and are broadly based on the voluntary Living Housing Australia (LHA) design guidelines. (For the current NDIS standards see NDIS (2019) and for LHA see (Livable Housing Australia, 2020)).

The second area is the NDIS's Home Modification Program. Similar to programs in several jurisdictions worldwide, the program provides funding assistance to people to modify their existing home in response to an acquired disability, or a progressive increase in assistance required due to a disability.



The NDIS recognizes three scales of home modification; simple home adaptations, minor home modifications (non-structural), and complex home modifications that require structural changes to the home (NDIS, 2020). Home modifications are assessed against the anticipated improvements in a participant's quality of life, and all costs are assessed against a "reasonable and necessary" criterion (Foster et al., 2016). In addition to new (or modified) housing from the NDIS, there are established community-based, or not-for-profit charity-based, housing stocks already in the community. Historically most of these took the form of group homes, but in recent decades have been moving towards housing people in the community. While independent, they rely on the NDIS for funding and for it to drive change and increase the available stock of appropriate housing.

Housing as a Place of Work for People with a Disability

People with disabilities experience discrimination in the workforce and accessing study (ABS, 2019; Australian Network on Disability, 2020). With work often difficult to access, stressful and mentally draining; part-time work is a common practice for people with a disability in the workforce, accounting for around 40% of people employed (Maritz & Laferriere, 2016). The benefits of working from home, with familiar environments and people, are reflected in the fact that people with a disability are more likely to be self-employed and/or entrepreneurs than people without disability (Maritz & Laferriere, 2016; Darcy et al., 2020). Australians with disabilities' rate of entrepreneurship, at 13%, is higher than the entrepreneurial 10% of employed Australians without disability. However, Government disability employment strategies are often directed to conventional, organization-based employment (Darcy et al., 2020). Regardless, people with a disability, whether in traditional salaried employment or self-employed are entitled to jodation (living in the community) has seen a strong growth trend, particularly among younger people with severe disability from 1 in 7 living in institutions in 1981 to 1 in 100 in 2003 (Australian Institute of Health and Welfare, 2008). The number of disability services users (across all service user groups) increased by around 50% between 2003 and 2009 to 279,000 individuals (Australian Institute of Health and Welfare, 2011). Currently, it is estimated that around 400,000 people are participants in the NDIS (out of an estimated 4.3 million Australians with a disability (NDIS, 2020). In addition, the support needs of service users have increased as well, the AIHW notes ... "in 2017-2018, 61% of disability service users always or sometimes needed assistance with self-care, mobility, or communication compared with 58% in 2009-2010" (Madden & Madden, 2019).

In addition to paid disability services workers, in Australia, it is estimated that 2,145,197 carers were providing unpaid assistance to a person with a disability, long-term illness or old age in 2016, more than 11% of the over-15 aged population (idcommunity, 2016).

METHODOLOGY

A desktop review was undertaken of the key policy documents that create the legislative environment through which housing is built in Australia. The housing industry is intrinsically linked to the social, economic, physical, and cultural identity of a society. As such, government policy incorporates housing issues at almost every level, including the provision of working from home. In Australia, as elsewhere, this incorporates tax policy, legal rights around ownership and tenancy, health and safety, and social policy around rent relief and aged care. However, this research focused on a narrower set of documents that relate specifically to the design of housing, reflecting the gap in the current dialogue around working from home. These included the Building Code of Australia, guidelines specific to apartment building in Victoria, and the design and funding guidelines for housing provision under the National Disability Insurance Scheme. Also included were Awards (workplace agreements from the Fair Work Commission in Australia), where they covered care workers working in the disability sector. The review focussed on the where these policy documents engaged (or not) with the reality of working from and in a home.



FINDINGS

The primary interventions into the Australian housing market by the Commonwealth Government rely on fiscal policy to encourage and stimulate market activity and demand. Whether investor-focused policies such as negative gearing and the capital gains offset, or first home buyer incentives and grants, these policies are 'design agnostic' and focus solely on price. As such, these interventions do not touch on working-from-home or working-in-home by support workers.

On the supply side, the National Construction Code does impact on, and regulate, the performance of a home (dwelling). It aims to 'set the minimum required level for the safety, health, amenity, accessibility and sustainability of certain buildings' (2019b, p. 8). The format of the Code first establishes performance requirements across the various criteria (safety, amenity, etc.), and then specifies acceptable built outcomes (or performance solutions, known as deemed-to-comply solutions). There is also an option for deemed-to-satisfy solutions that must be independently verified by qualified professionals.

There are three volumes of the NCC, Volume 2 addresses detached and semi-detached residential dwellings (Class 1 buildings), and Volume 1 with apartments (Class 2 buildings). However, in each of these documents, there is no specific mention of 'work' or 'workspace' in the code. The closest content describes the occupation and use of habitable rooms. Section 2.4 of Volume 2 deals with Health and Amenity. The sub-headings for this section include room heights (2.4.2), among others. The objective of room heights is "to safeguard the occupants from injury or loss of amenity caused by inadequate height of space" (O2.4.2). The functional requirement is that "a building is to be constructed to provide height in a room or space suitable for the intended use" (F2.4.2). The performance requirements for room heights state that "a room or space must be of a height that does not unduly interfere with its intended function" (P2.4.2). The verification method for room heights (V2.4.2), states that "compliance is verified where the height of the room or space provides an appropriate *activity support level* that does not unduly interfere with its intended use". In the explanatory information provided, it notes that; "the activities that are likely to be undertaken by occupants in the room, as well as the features of the activities, are relevant considerations when determining a suitable height", and that; "the method requires the consideration of *occupant characteristics* and *activity characteristics* and *activity support level*. When determining the activity support level, the method requires consideration of the relevant dimensions of items likely to be located in the room, as well as occupant circulation spaces" (Commonwealth of Australia and the States and Territories, 2019b, p. 60). Unfortunately, Volume 2 of the Code, dealing with private residences (Class 1 buildings) does not apply to people with a disability (the Access to Premises Standards apply to Volume 1 that describes Building Classes 2 to 9), and so occupant characteristics, and activity support levels do not include disability-related dimensions and circulation spaces.

The Victorian Government's new (2021) Better Apartment Design Standards (BADS) includes three sections: siting and building arrangement, building performance, and dwelling amenity. These specifically address apartments (Class 2 buildings), and the dwelling amenity section includes guidance to functional layout, room depth, and accessibility (among others). The functional layout section states that "[they] meet the needs of residents and room sizes and configurations appropriate for their intended use. Adaptable layouts provide for future household changes, which provide longevity of housing stock. The long-term needs of a community require a range of housing types, so people of different ages, backgrounds and needs are provided for" (Victoria & Department of Environment, 2021, p. 114). Minimum dimensions are noted for bedrooms and living areas, but no mention of workspaces or requirements are noted—and the accompanying sample plans do not show any workspaces. The guidance to accessibility states that "[it] promotes equal access to apartments for all community members including those with limited mobility, families with young children and older



people. Apartments which comply with the accessibility standard can easily be altered to meet changing needs of residents and ensure housing stock caters for a diverse range of household types over time” (Victoria & Department of Environment, 2021, p. 139). The requirements then detail minimum front door widths, internal corridor widths and the dimensions for an accessible bathroom.

Specialist Disability Accommodations (SDA) are dwellings that meet the requirements of the NDIS for funding and intentionally designed for people with a disability. The latest version of the SDA Design Guide (2020) lists twenty-five design standards that may be met in a variety of ways to qualify under one of the four categories of SDA dwelling. None of the individual standards mention working from home, nor do they require any provision for in-home support workers. This differs from earlier versions of the design guidelines for SDA, where the ‘Price Guide’ noted different returns (payments) for dwellings with or without overnight accommodation provisions (see NDIS (2019)). The guidelines do mention Breakout Rooms (Design Requirement 18), but that it “is not a study or living/dining area but is intended to be dedicated and used to enhance learning, exploration or positively impact mood” (NDIS, 2020, p. 68). The guidelines do note that the internet should be provided.

However, in another NDIS document concerning SDA dwellings, the *SDA Innovation Plan* notes that the housing should assist in “finding work nearby”—but not in the dwelling, and that “the aim of innovation is to enable new and innovative housing options to grow and transform old models of housing based on new patterns of participant demand” (NDIS, 2019, p. 6). Home Modification packages provided for in the NDIS are based around three scales that increase with cost and complexity. The modifications are subject to strict ‘reasonable and necessary’ criteria, and none of the guidance documents produced by the NDIS mention working from home. In the section on what can be funded, there is a recognition of carers in the home of a person with a disability, stating that:

The NDIS will fund reasonable and necessary home modifications: to the participant’s primary residence where, due to the impact of the participant’s disability, the participant or their carers are unable to reasonably access and use frequently used rooms and spaces using standard fixtures and fittings; and when the participant’s primary residence, in its current condition, has a significant and adverse impact on the sustainability of current living and care arrangements (NDIS, 2020).

However, in practice, modifications are limited to door widths, corridors, and bathrooms. In the section describing what the NDIS will not fund, working from home, or modifying workspaces is not mentioned. Although, it should be noted that no major home modification scheme in Australia or internationally includes funding options for workspaces. Extending the size of a dwelling or creating another bedroom (possibly for a carer) is not permitted under the current scope (NDIS, 2020). Interestingly, the Commonwealth Government post-COVID stimulus scheme ‘Homebuilder’ potentially does allow for the renovation or modification of workspaces, as it, (like other Commonwealth schemes) is design agnostic and not as prescriptive as the NDIS. However, it does offer \$25,000 for rebuilds that cost between AU\$150,000 and \$750,000 (NHFIC, 2021).

Finally, there is some design guidance where in-home support work is concerned in the workplace award for support workers. SCHaDS, the Social, Community, Home Care, and Disability Services Industry Award 2010 (Fair Work Commission 2020), which sets wages and conditions for support workers, in part states that “The span for a sleepover will be a continuous period of 8 hours. Employees will be provided with a separate room with a bed, use of appropriate facilities (including staff facilities where these exist) and freeboard and lodging when the employee sleeps over” (SCHaDS Section 25.7 Sleepovers, part c) and “The employee will normally have the opportunity to sleep during a 24-hour care shift and, where appropriate, a bed in a private room will be provided for the employee” SCHaDS Section 25.8 24 Hour Care Part B).



CONCLUSION

A report in 2020 by economists Sinclair, de Silva and Kopanidis surveyed in-home support workers about what disability-friendly design features improved the ability to do their jobs, identified that housing with disability-friendly design has market value, social value, and future value but that this is poorly understood by the general market, in particular the future value component. “The home is becoming more important in the caregiving process, with the support of telehealth and smart technologies. The home is thus capital in the giving process and as such can support the ease and efficiency of care provision when required within the home” (2020, p. 15)

Yet their survey of support workers cites access (dwelling access, internal doors, stairs) and personal hygiene (bathrooms, toilets, showers) as the major ways by which poor housing affects the ability to provide care. These are traditional concerns of disability design, either new build or home modifications, and personal hygiene is important as it is where most in-home support takes place (dressing, bathing, toileting). Likewise, assisted movement (small doorways and corridors, and steps) is an occupational health and safety issue. Lacking anywhere in these documents and policies is the kind of innovation that might “transform old models of housing based on new patterns of dwelling” The inversion of public and private space within a dwelling and of work and home offer enormous opportunities to rethink housing. Privacy (as we know it) is a very recent phenomenon—as is the separation of home and work—it is only a little over 300 years ago that Louis XIV first put up a curtain around his close stool (toilet) while receiving visitors (Flanders, 2015).

The research for this paper is a preliminary study limited to the Australian and Victorian context to identify gaps in existing legislation. The next step is to identify how these might be mapped to understand where legislation can be adapted to reflect current work circumstances and has meaning to the end user. A departure point would be the examination of comparative legislation from countries with similar housing industries such as the USA, Canada, the UK and Europe.

The design professions alone cannot resolve the multitude of issues around the changing face of working from home, given that these issues also include workers’ rights, health and safety, and taxation. However, while there remains a prevailing attitude that housing policy and workplace policy remain separate, there will always be a policy blackspot for people with disability, the carers who work with them, and people who work from home. This research poses the question for designers and policy makers alike; what are the implications that a lack of clear policies for planning and designing appropriate spaces and places to allow for working from home, and how will that effect the development of future accommodation in this category?

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Family members' perspective regarding safety behaviors and responsibility of Latino construction workers

Michael Merten¹, Joseph Grzywacz², Shannon Montgomery², Thomas Mills³, Elsa Nunez Reyes², Antonio Marin², Hector Nolasco⁴

¹University of Nebraska, USA, ²Lincoln, Florida State University, USA, ³Virginia Polytechnic University, USA,

⁴California State University, Bakersfield, USA

Correspondence: michael.merten@unl.edu

ABSTRACT

Family is a major agent for change, regardless of whether the focus is on disease management, educational success, or safety in the workplace. The current study aims to examine beliefs about worker safety from the perspective of family members of small-scale Latino construction workers and provide insight into issues of promoting safety in the workplace and beliefs about responsibility as it relates to accidents and injuries that occur on the job.

Qualitative semi-structured interviews were conducted with 18 family members of small-scale Latino construction workers in the framing and roofing trades. The 60-90 minute interviews were audio-recorded, transcribed verbatim, and analyzed for dominant themes.

Preliminary data finds that family members are aware of the dangers that the Latino construction workers face. Interviews suggest that family members (largely spouses) acknowledge that family members are to varying degrees familiar with unsafe behaviors exhibited on the worksite. In regards to family members' involvement in encouraging worker safety, family members communicate messaging about safety to workers in both passive ways and methods that involve "thinking about family."

The generalizability of study findings is unknown because the data are from a small, regional sample of contractors and workers in two trades of small-residential construction.

Understanding the perspectives of family members of small-scale Latino construction workers regarding safety behavior and responsibility is a novel approach to creating worker education programs that have the potential to be more effective than traditional worker/contractor only programs.

An opportunity exists for family members to become more actively involved in promoting safety practices of the worker. The inclusion of family members in small-scale residential construction safety programming may significantly reduce serious injury in the workplace.

Keywords: accident, family members, immigrant Latino workers, qualitative research, safety, small-scale residential construction.

INTRODUCTION

Immigrant Latino workers experience substantial injury disparities in the construction industry. Fatality risk is 40-80% higher among Latino workers than non-Latino construction workers (Dong & Platner, 2004); injury risk is 30% higher among Latino construction workers (Dong et al., 2010a). Injury rates among construction workers are likely underestimated, especially among immigrant workers (Dong et al., 2010b; Schoenfisch et al., 2010) who view risk as part of the job (Brunette, 2004; Lipscomb et al., 2005).

Family members of construction workers have historically been overlooked in safety strategies targeting Latino construction workers. Workers' family members (e.g., spouse, parent, aunt/uncle) may play a critical role in encouraging their loved one to be safe. *Familismo* or the strong sense of



responsibility for, and loyalty to, family (Cauce et al., 2000) is a cultural value for Latinos. Family is a major agent for change, regardless of whether the focus is on disease management, educational success, or safety in the workplace. The current study aims to examine beliefs about worker safety from the perspective of family members of small-scale Latino construction workers and provide insight into issues of promoting safety in the workplace and beliefs about responsibility as it relates to accidents and injuries that occur on the job. Small-scale construction is defined in this study as construction crews that consist of 6 or fewer workers.

This study will examine whether families are aware of the dangers faced by their construction worker family member. If family members are aware of the dangers of the work of their loved one, family members could become a strong ally in encouraging safe behavior on the jobsite. Additionally, this study will examine family members' perspectives of whether they currently promote safety of their construction worker family member and whether they feel they have the ability to promote safety of their family member in small-scale construction. Understanding the perspectives of family members of small-scale Latino construction workers regarding safety behavior and responsibility is a novel approach to creating worker education programs that have the potential to be more effective than traditional worker/contractor only programs.

Rauscher (2012) explored the role that the social context of the workplace may have on the safety practices of young construction workers, specifically whether construction firm size and the composition of individuals working in the construction firm (working in a firm owned by a family member or one in which a family member also works). This study yielded findings that indicate family member presence on the worksite may play a protective factor in construction worker safety. The current study builds on this literature to further examine the social ecological influence of family members of Latino construction workers and their subsequent safety behaviors. The social ecological model (Bronfenbrenner, 1977) recognizes the multiple levels of influence that guide the behavior of individuals. Those levels of behavior include public policy, community, organizational, interpersonal, and individual. The current study focuses on the interpersonal level of influence, specifically, the construction worker's family. At the interpersonal level, family members can have regular talks with their construction worker family member about the dangers of construction work, but more specifically communicate effective messages that will allow them to enhance safety behaviors of their construction worker family member.

METHOD & MATERIALS

Study Design

This research is part of *iPonte Listo!*, a study of occupational safety among immigrant Latino workers in the small-scale segment of the residential construction industry being carried out in Tulsa County, OK. *iPonte Listo!* uses a sequential mixed-method design with two primary components. The first component is formative in nature and involved the collection of qualitative data through in-depth personal interviews with family members (primarily spouses) of Latino construction workers. The second component is forthcoming and will involve testing of a randomized-controlled trial of intervention materials developed based on knowledge gained from the first component. The data for this analysis are from the qualitative component of the project.

Recruitment and Sample

We recruited one family member of 18 Latino construction workers. Inclusion criteria for participants in this study included: (1) being a first-degree relative (i.e., spouse, sibling, parent) of an immigrant Latino construction worker; (2) the construction worker labors primarily in residential construction as a framer, general laborer, or roofer; and (3) the construction worker has labored for at least 6 months



in the past 2 years in residential construction. The vast majority of family member interviews were with a spouse (17 of the 18 interviews). The research team has a 50-year collective history of working with the immigrant Latino population, and a 25-year presence in the local community. Recruitment was therefore facilitated by a large network of relationships with organizations and agencies serving the immigrant Latino community. All potential participants were referred to study staff by individuals in this network of community contacts. Study participants were recruited by trained bi-lingual study staff.

Data Collection

Data were collected from December 2019 through July 2020, by two trained interviewers. Interviewers met participants at locations of the participants' choosing, usually their homes, explained the project, and obtained signed informed consent. Data collection did span the COVID-19 pandemic, resulting in 10 interviews that we conducted in an in-person, face-to-face environment, and the remaining 8 interviews were conducted through Zoom. Participants received a \$25 incentive at the end of the interview. All procedures were approved by an Institutional Review Board. Digitally recorded interviews ranged in length from about one to three hours.

Interview Content

The goal of the qualitative component was to build an understanding of the knowledge and beliefs surrounding occupational safety and injury held by family members of Latino construction workers. Interviews began with basic information about the participant. Then the interview moved into questions to probe basic beliefs about job hazards (something that has the potential to cause harm), risks (likelihood of harm taking place, based on exposure to a particular hazard) confronted by workers, and the perceived causes of common injuries experienced by construction workers including falls from heights, strains, and injuries from equipment.

Analyses

All interviews were digitally recorded. The 18 family member interviews were transcribed verbatim in Spanish, and then translated into English by a professional transcription service. All investigators reviewed each of these transcripts and determined that theoretical saturation had been reached. All the translated transcripts and case summaries were uploaded into NVivo 12 (Version 12 QSR International Pty Ltd. NVIVO qualitative data analyses software, 2018) for data management, coding, and to facilitate analysis. A coding dictionary was constructed based on a-priori content underlying the construction of the interview guide (e.g., controllability of injury, beliefs about safety) as well as new ideas that emerged from immersion into the data. Two team members independently coded each transcript and case summary. The vast majority of codes had excellent inter-rater reliability (Kappa ranged from 0.8 to 1.0). Some of the codes had poorer inter-rater reliability, but coding agreement was achieved through consensus.

RESULTS

Participant Characteristics

The current study included 18 family members of immigrant Latino construction workers. All participants were female and all, but one participant was married. The average age of study participants was 35.83. In addition, the average number of years study participants have lived in the United States was 17.11 years. Table 1 shows complete demographic information for the study sample.



Table 1. Demographic information for study sample.

Family members of Immigrant Latino construction workers

Interview #	Age	Years in the United States	Gender	Marital Status	Years of Education
1	28	2	F	Single	Universidad
2	24	8	F	Married	10th grade
3	50	23	F	Married	8th grade
4	34	--	F	Married	9th grade
5	61	30	F	Married	--
6	32	32	F	Married	High School
7	30	11	F	Married	7th grade
8	21	4	F	Married	9th grade
9	31	13	F	Married	High School
10	31	30	F	Married	10th grade
11	29	12	F	Married	11th grade
12	38	8	F	Married	Universidad
13	28	7	F	Married	Universidad
14	33	24	F	Married	GED
15	44	30	F	Married	11th grade
16	46	22	F	Married	High school
17	44	21	F	Married	GED
18	41	14	F	Married	9th grade

The current study aims to examine beliefs about worker safety from the perspective of family members of small-scale Latino construction workers and provide insight into issues of promoting safety in the workplace. Analyses of interviews of family members of immigrant Latino small-scale construction workers yielded two primary themes. The first theme that emerged was the perceived risk of the dangers of construction work by family members. Within this larger theme, a sub-theme emerged that provided specifics related to family members' knowledge of unsafe behavior of workers. The second theme that emerged in the study findings focused on family members' actions to promote the safety of their construction worker family member.

Theme 1: Perceived risk of the dangers of construction work by family members

In general, many family members of small-scale immigrant Latino construction workers believe the work their family member engages in is a dangerous and risky occupation. Family members largely form this opinion based on things their construction worker family member have told them about their job. One family member commented:

I think, it's (construction job) also dangerous because several accidents have happened. My husband told me the other day that somebody's machine turned over while it was being operated. I got very worried because he works there.



In addition, a few family members perceive the construction occupation as dangerous because they have been to their family member's worksite. One spouse stated,

Well, I've been to his worksite, and he's told me about it. I know it's a job full of risks. It's dangerous.

Yet another spouse who indicated that they work with their husband on the construction crew commented:

I work with him - taking him water and all the supplies he might need. When the house is very steep, for example, a 12 or a 16, his job is dangerous. On those houses, they have to wear a harness. They also have to wear a harness when they work on a two-story house.

While family members overwhelmingly felt the construction occupation was dangerous, we were interested to further examine the degree to which family members had knowledge of specific dangers or hazards on the jobsite and/or unsafe behaviors by their family member or other workers in the crew.

Sub-theme A: Family members' knowledge of unsafe behavior of workers and the workplace

Results indicated that many family members are familiar with the unsafe behaviors of workers and the work environment. As one family member of a construction worker commented:

The scaffolding is not well-made. Due to the scaffolding not being right, he had the accident I mentioned to you earlier. It wasn't set up right on the ground. He also says the electric cords are broken, sometimes, and they can be electrocuted by them, or the nail guns can put a nail in your hands or legs. I mean, he's always at risk.

Another family member admitted that they were aware of the unsafe behaviors that are exhibited on the work site by their family member employed in construction:

The workplace is unsafe. They don't wear helmets. At least, I know my nephew doesn't wear a helmet. They don't use a harness. They don't wear goggles to protect their eyes.

Some family members expressed a greater understanding of the array of dangers present to workers on the job site. For most respondents, they indicated the lack of PPE use among many of their family members as well as the great heights that workers must work from frequently. As one family member commented:

There are a lot of things they're exposed to at work. Not only the weather, but to other things, such as, picking up the trash, or having a roof tile bundle fall down and hit them on the ground. Or they can step on a nail and get injured. There are some materials they put on the roof corners that are very sharp. And if they don't wear gloves, they can cut their hands. But, more than anything, it's the heights because, sometimes, they don't wear any kind of protective equipment.

Theme 2: Family members' actions to promote the safety of their construction worker family member

The analyses of interviews yielded differing views relative to the responsibility and/or the actions of family members that may promote the safety of their construction worker family member. The interviews with family members yielded four distinct findings.



Sub-theme A: Family members do not perceive themselves as the primary change agents for promoting safety behavior among workers

Some participants spoke about the lack of impact they have on influencing the safety behaviors of their family member. One family member commented,

Well, I don't think family members can help. The only thing they can do is to tell them to be careful because they're not at the worksite. So, I repeat, the only person who can do something is the crew leader. I, as a family member, can tell my husband to be careful.

The family member in this case is making the point that in order for someone to be impactful with promoting the safety behavior of a worker, the person must be present on the job site to do so. In fact, the family member goes on to mention that the crew leader is the only person that can make sure workers are working safe on the job. Another family member reiterated the importance of the "boss" in ensuring worker safety:

We have to tell them (workers) to stop pressuring themselves so much. We have to tell them that they should work hard, but they shouldn't do everything to please the boss.

Family members were also asked about substance use on the job and again the emphasis by one family member was on the crew leader as the person responsible for promoting safety on the job site:

Well, the only thing family members could do is tell them not to drink on the job. The only person who can do something about it is the crew leader. He's the one who has to say, "I don't want you drinking on the job."

Sub-theme B: Passive approach related to promoting worker safety

In many instances throughout the interviews with family members, there was a strong sense of passiveness in their approach to promoting safety behaviors to their construction worker family member. A few family members reported that they never talk to their construction worker family member about their job, while many other family members in regards to safety messaging, simply convey passive messages. One family member commented:

I just tell him to be alert and to take care of himself. And he responds, "I'll do that."

Another family member relays a similar type of message to their construction worker spouse on a daily basis:

I tell him to be careful at work. There are a lot of things they're exposed to at work.

Yet another family member comment provides another illustration of a message being conveyed to a worker that focuses on "being safe", but not providing any specific information to the worker in which how to do so:

Well, we're in a world where we don't know what is going to happen. So, I try to tell him to take care of himself because something might happen at any moment. We never know what might happen.

Sub-theme C: Action approach related to promoting worker safety



Several family members who were interviewed were more active in their pursuits to ensure that their construction worker family members were being safe at work. One family relative commented:

I tell him every day, to be careful and not spend too much time on the phone, and that he needs to be careful about what he's doing. Because you know that young people get distracted by the phone.

In this instance, the family member provided more specific direction to the worker in the form of being specific about what they should or should not do (spend too much time on phone) and provided a justification as to the harm in being on a phone too much during work. Family members in other instances talked about ways that they promote safety among their construction worker family members, which include both actions done by family members that indirectly can lead to greater worker safety without the need to be on the worksite.

I tell him he should go to bed early. If I see it's 11 p.m., and he's awake, I tell him to go to sleep because he has to go to work the next day. But my duty is to tell him to go to bed and rest. In the morning, I get up early to make him breakfast so he can go to work well fed. I don't want him to fall because he didn't eat.

Throughout the interviews, few family members reported that they were aggressive in making sure their construction worker relative was planning to use or was prepared to use proper PPE while at work. However, one spouse shared her experience related to her actions in promoting safety practices:

I always make sure my husband puts his harness, and helmet in his truck. Before he goes to work, I always ask him, "Are you taking all your tools and safety equipment?"

Sub-theme D: "Think about your Family"

In regards to the communication that takes place between family members and their construction worker relative, family members frequently direct their worker family member to "imagine" what would happen if they were to get injured or die on the job. Specifically, the emphasis is to **think about** other family members that would be impacted by their injury/death as a result of not working safely.

I tell him, since I don't work, "Imagine what could happen to us if we didn't have you. If you don't support us, how are we are going to be able to survive? How are we going to pay for the house?" And not only us, but my mother and his mother are in Honduras. It's going to hurt them if something happens to him.

Another family member said the following:

Well, what I do is make him think about his family. I tell him about what would happen to us if something happened to him. I'd find a job, but, as you know, women are paid less than men. So, I let him know he needs to take precautions on the job because it's very dangerous.

In addition to the focus on family members instructing workers to think about their family when engaging in their work, one spouse mentioned the following as a method of promoting safety behaviors:

I'd make his children talk to him because his children are the reason he gets up every morning to go to work.



DISCUSSION

The current study examined the broader issue of Latino construction worker safety by focusing on an extremely understudied population (family members of construction workers), in order to understand perspectives of construction worker safety and ultimately gauge the potential of family members as critical agents to promote greater safety behaviors through effective messaging and communication with their family member.

An opportunity exists for family members to become more actively involved in promoting safety practices of the worker. The inclusion of family members in small-scale residential construction safety programming may significantly reduce serious injury in the workplace. The results of this study provide information related to family members' knowledge of construction worker safety and safety practices on the worksite. Specifically, results of this study show that most family members perceive their family member's construction job as dangerous and/risky. In addition, most family members are aware of the unsafe behaviors that are exhibited on the worksite by their construction worker family members and/or crewmates. The awareness of the unsafe behaviors on the worksite are predominately as a result of information they have received from their construction worker family member related to their prior injuries suffered on the job or stories they have heard about other construction workers being injured on the job. To a lesser degree, family members views of unsafe behaviors on the worksite is a result of having any prior experience with being physically present on the worksite. Data further suggests that family members (largely spouses) acknowledge that workers do not take the necessary safety precautions such as wearing hard hats, safety glasses, or harnesses.

This study also provides valuable information related to family members' approach in promoting safety behaviors among their construction worker family members. It provided information as to whether or not, to what degree, and what method family members of construction workers promote safety practices. Many family members provide messaging to their construction worker family member in the form of "passive" messaging, which largely includes statements such as, "be careful" or "stay safe". These messages do not provide specific actions. These types of messages may not carry the same impact as other messages in promoting and encouraging safer practices on the job. Some family member participants do report using messaging that encourages their family member worker to "think about" their family members, specifically their children when they are working. This approach challenges the worker to think about the long-term consequences of their potential unsafe working practices. Family members of construction workers have historically been overlooked in safety strategies targeting Latino construction workers. Results of this study lend support to the notion that workers' family members (e.g., spouse, parent, aunt/uncle) may play a critical role in encouraging their loved one to be safe and the importance of *Familismo* or the strong sense of responsibility for, and loyalty to, family (Cauce et al., 2000) in influencing the safety behaviors of Latino construction workers.

The interpersonal level of the social ecological theory as it relates to promoting worker safety among Latino construction workers consists of family members, friends, and co-workers. The current study focused specifically on family members' as possible influencers of safety behavior by construction workers. Results indicate that most family members of Latino construction workers provide some level of safety messaging to the worker, whether passive ("Be careful") or strategies asking the worker to "think" or "imagine" what life would be like if they were severely injured or died on the job, thus providing support for the importance of the interpersonal (family) dimension of the social ecological framework and the potential for producing change in the safety behaviors of small-scale Latino construction workers.



Results from this study come from interviews from 18 family members of Latino construction workers. Specifically, this data was collected from family members whose family member worked in small-scale construction (crews that consist of 6 or fewer workers), thus we caution that the results from this study may not be generalizable to family members of Latino construction workers who are part of larger working crews.

Future directions for this work include providing interpersonal strategies/training to family members of Latino small-scale construction crews so they can engage in conversations with their spouse/family member that will allow them to provide more specific safety messaging to their family member. Instead of simply telling them “to be careful”, it may be more effective for family members to provide more specific and direct messaging such as, “be sure that you will drink lots of water today and not get on ladders that are not tied off.” Those are specific behaviors that may allow the worker to think conscientiously about during their work day.

Conflict of interest statement

None of the authors have any financial or personal relationships with other people or organisations that could inappropriately influence (bias) their work.

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A REVIEW OF THE COSTS OF ACCIDENT IN GCC CONSTRUCTION

Tariq Umar¹, Nnedinma Umeokafor²

¹Kingston University, UK, ²Liverpool John Moores University, UK

Correspondence: tariqumar1984@gmail.com

ABSTRACT:

Construction industry in the Gulf Cooperation Council (GCC) member countries is at peak as the region is in the stage of developing its major infrastructures. The development projects in the GCC have made the region as a major jobs hub for both local and international workforce but at the same time these projects have also resulted into several issues including poor safety performance. This article attempts to estimate the costs of workplace accident in construction using qualitative research approach and considering different parameters. The data from three countries Qatar, Oman and Saudi Arabia was used to estimate the cost of accident in GCC region. The parameters used in these estimates include the i) values of the current projects in the selected countries, ii) average cost of accident in United States of America (USA) and United Kingdom (UK) and iii) compensation cost. The average cost of an accident in USA, UK, Australia (ASU) and South Africa (SA) was used for comparison of the costs of accidents in Qatar, Oman, and Saudi Arabia. The total costs of an accident in Oman are estimated at US\$ 415,620 with an economic burden of US\$ 205.73 Million/year on Omani economy. In Saudi Arabia, the costs of an accident are estimated at US\$ 91,940, while the economic burden of the Saudi economy is estimated at US\$ 261.11 Million/year. The findings of this research will be useful to understand the cost implication of accidents in construction, and thus will be helpful to motivate the construction organizations to invest in safety related issues and avoid accidents. One of the main limitations of this research is that the direct costs are calculated from the indirect costs of accidents due to the lack of available data. Further research is needed to estimate the direct costs of accident in the region.

KEY WORDS: accidents, construction, costs of accidents, economic burden, GCC region.

1. INTRODUCTION:

Accidents in construction include not only direct physical injury to persons or damage to property, but also short-term and long-term effects or incidents due to other exposures on sites that affect the workers' health and physical well-being. Costs associated with accidents in the construction industry can be categorized as direct and indirect costs (Umar, 2019). Direct costs tend to be those associated with the treatment of the injury and any unique compensation offered to workers because of being injured and are covered by workmen's compensation insurance premiums. Indirect costs include reduced productivity for both the returned worker(s) and the crew or workforce, clean-up costs, replacement costs, costs resulting from delays, supervision costs, costs related to rescheduling, transportation, and wages paid while the injured is idle (Hinze, 1994). The costs of accidents (direct and indirect) can be substantial. Research conducted in the UK showed that indirect costs are eleven times more than direct costs (Mfi, 2003). The costs of accidents in the USA were determined as 6.5% of the total value of completed work and in the UK, it is approximately 8.5% of the tender value (BRT, 1995; Anderson, 1997). Waehrer et al., (2007) considered that costs of work-related accidents which result into injuries and sickness can be classified into main three categories of a) direct costs, b) indirect costs, and c) quality of life cost.

A research conducted in the UK on cost and benefit analysis revealed that when total costs of accident prevention were compared to the total benefits of accident prevention, the benefits far outweigh the costs of accident prevention by a ratio of approximately 3.1, which means that when contractors,



irrespective of their sizes, spend £1.00 on accident prevention, they gain £3.00 (Ikpe et al., 2012). The cost of accidents can be understood by contractors and represents a tangible measure that can be related to project financial accounts and both the income statement and balance sheet of a contractor (Tang et al., 2004; Booth and Panopoulos, 2005, Umar, 2020). Thus, this category of cost is very often at the forefront of considerations of the costs of health and safety.

Top management of small construction organizations are reluctant to spend money on the occupational safety and health. This is due to the facts that accidents normally do not happen in construction projects on regular or daily basis (Agumba and Haupt, 2012; MacEachen et al., 2010). It is therefore essential that the top management should have an awareness of the costs of accidents in their projects. This will help them to change their perception and will make them prepare to spend on the safety and health matters. Hinze (2006) noted that if the actual cost of accidents is well known to the management, they will be able to make effective decision related to the safety and health in their organizations or projects. The cost of accidents will enable top management to consider the safety and health not only a part of workers well-being but also from an economic perspective. The cost of accidents would also be more attractive for owner as there could be great economic benefits for them. In this regard, the relationship between costs of safety and health and its benefits was best projected by Ikpe et al. (2012). The study indicates that if the prevention costs reduce, the costs of accidents will increase. Likewise, if the cost of prevention will be more the benefits arising from low number of accidents will more.

There have been several research studies around the world in which an attempt is made to estimate the costs of accident in construction; however, there is no study on the costs of accident in construction in any of the GCC country (Umar, 2017). In this article an attempt is made to estimate the costs considering the three GCC countries including Qatar, Oman, and Saudi Arabia.

2. COSTS OF ACCIDENT IN CONSTRUCTION:

A research study funded by Centre to Protect Workers' Right (CPWR) in the USA reported that the average cost of fatal or non-fatal injury arising from accident in construction is US\$ 27,000. This cost is almost double than the average cost of fatal or non-fatal injury in other industries which stood at US\$ 15,000 (Waehrer et al., 2007). The statistics published by the National Institute of Occupational Safety and Health (NIOSH) in USA indicates that the average cost of an accident which results into the death of a worker is US\$ 867,000 (NIOSH, 2006). This cost, however, do not include the cost of quality-of-life losses. The average cost of a fatal accident in the construction industry of USA estimated by Waehrer et al. (2007) stand at US\$ 1.0 Million, which is comparatively more than the estimate made by the NIOSH. Overall, if the cost of the quality-of-life losses is also added with the average cost of a fatal accident in construction, then the total average cost will stand at US\$ 4.0 Million (Waehrer et al., 2007). In other words, the cost of the quality-of-life losses resulted from a fatal accident in the USA is equal to US\$ 3.0 Million. In terms of direct costs of non-fatal accidents in the USA construction industry, which required medical treatment, was estimated at \$777 (Miller et al., 2002; Waehrer et al., 2007). This however does not include the cost of work or productivity which stood at US\$ 618 (Miller et al., 2002). Thus, the direct cost of non-fatal construction accidents required medical treatment with cost of work or productivity can be estimated at US\$ 1,395 (777+618 = 1,395). Similarly, the direct cost of a fatal accident which requires medical treatment in the construction industry of USA cost around US\$18,300 (Miller et al., 2002; Waehrer et al., 2007). This can be translated to an average direct cost of accident, either fatal or non-fatal, which is equal to US\$ 9,850.

A research study on the cost of accidents carried out in SA considering a total of 100 different types of accidents including 14 fatal accidents, estimated the total cost, including direct and indirect, of all these accidents at US\$ 2.37 Million (Haupt and Pillay, 2016). The direct cost of all these accidents was estimated at US\$ 0.726 Million, while the indirect cost of accidents stood at US\$ 1.64 Million, double than the direct cost. This can be translated that one accident in SA either fatal or non-fatal cost around



US\$ 23,700. The direct cost of one accident in SA can be therefore US\$ 7260, while the indirect cost will be US\$ 16,400. The cost of one accident either fatal or non-fatal estimated in the USA (~US\$ 27,000) and in SA (~23,700) are comparable as the difference between both the estimates stand at 12.30%.

Similarly, the HSE (UK) report published in 2011, on the cost of accidents, which considered the 2006 – 2007 available data, established the direct cost of a total of 1,385,232 accidents and illness was US\$ 21223.21 Million (HSE, 2011). The direct costs of one accident (fatal or non-fatal) in the UK will therefore cost US\$ 15,300 if all the accidents including fatal, non-fatal with major or minor injuries and illness are considered. This direct cost of one accident in the UK (~US\$ 15,300) is double the direct cost of an accident in SA (~US\$ 7,260). This may be due the fact the direct costs of one accident in UK also include the cost of illness; however, the direct costs of an accident in SA do not include this. If the direct cost of an accident in UK is calculated based on the fatalities and injuries accidents only, then this will be equal to US\$ 10,370, which represents a difference of 30% between the UK and SA accident costs. The UK direct costs of an accident (~US\$ 10,370) is closer to the direct cost of accident in the USA (~US\$ 9,850), the difference is only 5%. If the average costs of the accidents which involve fatalities or major injuries are considered, the cost per accident in UK will stand at US\$ 24,000.

Statistics published by the “Safe Work Australia” indicates that in 2012-2013, work related accidents which resulted injuries and illness put a burden of US\$ 44.02 billion on Australian economy. This is a huge amount which is equal to 4.10% of the total Australian GDP (SWA, 2018). The statistics further reveal that most of the cost (~95%) was borne by the workers and society. To be more specific, the workers bear 77%, society bear 18% and employers bear 5% of the total costs of accidents in AUS. Accidents which result into injuries are accounted for US\$ 19.95 billion (~45%) of the total cost. Roughly, the direct cost of an accident in AUS is estimated at US\$ 27,100, which is almost the same as the direct cost of accident in USA (~US\$ 27,000).

The statistics related to the costs of accidents quoted from USA, UK, SA and AUS show that the costs of accidents in these countries are not the same, but in the range of US\$ 23,700 ~US\$ 27,100 which gives an average value of the costs of accident (~US\$ 25,450). This average cost of an accident (~US\$ 25,450) is used in this research for further analysis.

3. COST OF ACCIDENTS IN GCC:

The Cost of Accidents in GCC construction estimated in this research is based on several assumptions and co-relations as there is a lack of availability of the raw data. For example, there is no organization in any of the GCC country like the organizations available in the USA (for instance OSHA), UK (for Instance HSE) or AUS (for instance Safe Work Australia). The cost of accidents is estimated from the available data considering three countries from the GCC including Qatar, Oman, and Saudi Arabia. These countries were selected because relevant data required were only available (publicly) in these countries. The parameters used for cost estimation include values of projects, average percentage of accidents costs (7.5% of the project value), and compensation costs of accident (indirect cost). The direct cost of an accident in this research is calculated from the indirect cost. The total cost is then calculated by adding direct and indirect costs.

3.1 Cost of Accidents in Qatar:

The cost of accidents in Qatar is calculated based on the value of construction projects in 2018. The data published by a unique conference series related to the projects in Qatar “Project Qatar” shows that the value of Qatar major construction projects stood at US\$ 117.44 Billion (PQ, 2018). Since such costs of accidents is not established in any of the countries in GCC, therefore the costs of accidents in Qatar construction projects in estimated based on the current projects’ values and average costs of accidents established in the USA and UK (BRT, 1995; Anderson, 1997). The average ratio of the costs



of accidents in both the countries is equal to 7.5% ($6.5+8.5/2 = 7.5\%$). Based on this rule, the total costs of accidents in the Qatar construction industry will be US\$ 8,808 Million.

Likewise, one of the main projects which has attracted the attention of the local and international organizations not only because the next football world cup will be held here but also because of the workers deaths in this project. Some of the reports show the number of construction workers that died in this project has already reached 1,200. Several estimates predicting the number of deaths will reach to 4000 by the end of 2022 when the project will be completed (SM, 2018; ITUC, 2014; Ganji, 2016). If the costs of these accidents are estimated on the assumption that a fatality costs in UK and Qatar are the same (~US\$ 1,870,437), 1,200 fatalities will result into a total cost of US\$ 2,245 Million. Similarly, if the death toll will be reached to 4,000 deaths by the end of this project, this will put a burden of US\$ 7,482 Million. Of course, this should be considered that this estimate presents the costs of fatalities arising from accidents in one construction project. This reflects that the actual burden on Qatari economy from the costs of accidents in construction will be much more than the one quoted here.

In the third estimate the statistics published by the General Retirement and Social Insurance Authority (GRSIA) of Qatar for the year 2017 were used. These statistics show that there were 75 deaths and one disability caused by work related accidents in 2017. This is important to note that GRSIA only register Qatari or GCC citizens into its insurance system. The total expenditures (benefits) caused by these deaths (~USD 4.31 Million) and disability (~1.37 Million) were US\$ 5.68 Million (GRSIA, 2017). The average indirect costs of one accident result into death or disability is therefore equal to US\$ 74,737. To determine the direct costs of these accidents, the equation developed by Haupt and Pillay (2016) were used. The assumption here is that the direct costs of an accident is half of the indirect costs. The total costs of an accident are calculated using equation No.1, which is equal to US\$ 205,526. The costs of accident in Qatar (~US\$ 205,526) are almost nine times more than the average costs of an accident in USA, UK, AUS and SA (US\$ 25,450).

$$TCA = DC + 2.25 IDC \quad \text{.....Equation No.1}$$

Where;

TCA = Total Costs of an Accident

DC = Direct Costs of an Accident (~US\$ 37,368)

IDC = Indirect Costs of an accident (~US\$ 74,737)

3.2 Cost of Accidents in Oman:

The cost of accidents in Oman is calculated on two different parameters. The first parameter is the same as used Qatar, the construction projects values. The second parameter used to estimate the cost of accidents in construction in Oman is based on the raw data obtained from the Public Authority of Social Insurance (PASI). The construction projects data for the year 2015-2016 shows that the total value of different types of development projects was US\$ 163,568 Million (Umar, 2017). If it is assumed that the cost of accidents in USA, UK (= 7.5% of the project value) and Oman are comparable and the average values of the costs of accidents from USA and UK is applied in Oman, the total costs of accidents will be US\$ 12,268 Million.

The second estimate is based on the data obtained from the PASI in Oman which registered only Omani citizen in the system. The data shows that a total of 495 cases of work-related injuries were disbursed. The total number of active insurees by the end of 2017 was 233,859 (PASI, 2017). The costs of these accidents are calculated based on the average cost (~US\$ 25,450) of an accident derived from the average costs of accidents in USA, UK, AUS and SA which is estimated at US\$ 12.59 Million. The



amount of compensation disbursed by the PASI in 2017 against these cases (~495) is equal to US\$ 8.16 Million or US\$ 151,135 per injury. This can be classified as indirect cost of the injury as this amount do not include the direct costs such medical treatment etc. The comparison of this indirect cost of injury in Oman (~US\$ 151,135/injury) with indirect of accident in SA (~US\$ 16,400), reflect that the indirect cost of an injury in Oman is almost 10 times more than the cost of an injury in SA. To determine the direct costs of these accidents, the equation developed by Haupt and Pillay (2016) were used (equation No.1). The assumption here is that the direct costs of an accident is half of the indirect costs. Thus, for the calculation of the total costs of an accident in Oman, the direct costs are considered as US\$ 75,567 per injury ($151,135/2 = 75,567$). The total cost of an accident in Oman is thus estimated at US\$ 415,620, which is 16 times more than the average costs of an accident in USA, UK, SA and AUS (~US\$ 25,450). The total costs of an accident in Oman result into an economic burden of US\$ 205.73 Million per year on Omani economy.

3.3 Cost of Accidents in Saudi Arabia:

The costs of accidents in Saudi Arabia are calculated based on two methods, which are a) the values of the total projects in different sectors in Saudi Arabia and using a cost of accidents ratio which is 7.5% of the value of the projects; and b) the number of different types of accidents using an average obtained from a reliable source and using the average costs of an accidents determine from the costs of accidents in USA, UK, SA, and ASU. The values of the different types of projects during 2015 to 2018 was obtained from the Venture Onsite website, which is of the leading organization tracking the construction projects across the Middle East and Africa region for more than 15 years (Venture Onsite, 2018). To determine the costs of accidents in the development projects in Saudi Arabia, the average percentage (~7.5%) as the costs of accidents is used. Since, in this method the costs are dependent of the value of the projects, therefore as the value of the projects reduce the costs of accidents reduced as well. For instance, the costs of accidents in 2018 are less than the costs of accidents in 2015. This do not represent that the safety performance in 2018 has been improved compared to 2015. But the fact is that the projects values are less in 2018 than in 2015. This was due to economic conditions of the country which is heavily reliant on the oil and gas earning. The dip in petroleum prices has also affected the development projects not only in Saudi Arabia but across the GCC.

In the second method of estimating the costs of accidents in Saudi Arabia, the raw data was obtained from General Organization for Social Insurance (GOSI), Saudi Arabia. The only accidents resulting injuries, data which is available on the website was for the third quarter of 2018. Since the data for the whole year was not available; the numbers of different types of accidents were multiply by 4 considering that GOSI divide one year into four quarters and assuming that the numbers of accidents in other quarters of 2018 were the same (GOSI, 2018). The total number of accidents resulting into injuries or deaths in 2018 was estimated at 31,104. The average costs of one accident determined from the data obtained from USA, UK, SA and AUS was US\$ 25,450. Thus, the total costs of these accidents will result a burden of US\$ 791.59 Million to the Saudi economy. If the costs of these accidents are estimated based on average costs of accident in Oman (~US\$ 415,620), this will result into a total cost of US\$ 12927.44 Million.

Likewise, the statistics published by the GOSI shows that in the third quarter of 2018, a total of US\$ 13.44 Million were disbursed against the disabilities or deaths caused by accidents at workplace (GOSI, 2018). The total number of disabilities (~386) and deaths (~16) in the same period were 402. Thus, the indirect costs per accident which result into a disability or death can be therefore estimated at US\$ 33,433. Although, this cost as an indirect cost is comparatively low than the indirect cost of accident in Oman (~US\$ 151,135), however it is still double of the indirect cost of accident in SA (~US\$ 16,400). The total cost of an accident in Saudi Arabia is estimated using equation No.1, assuming that the direct costs of accidents is half of the indirect costs. Thus, for this calculation the direct costs of accident are assumed as US\$ 16,716. The total costs of an accident in Saudi Arabia are thus estimated at US\$ 91,940. If the rate of disabilities and deaths arising from accidents in other quarters of the year will be



the same, then the total number of such accidents could be 1,608 (= 4 x 402). The total burden of these accidents on Saudi economy will be therefore US\$ 147.84 Million per year. This is important to note that this amount could be more than what is estimated here as there are still cases (~3,372) in the same quarter which are still under treatment. Overall, the disabilities and deaths in the same quarter represent 9.12% of the total treated cases. If the same percentage of disabilities and deaths is applied on cases which are still under treatment, there will be a further of 308 cases which could end with disabilities and deaths. The total economic burden on the economy in one year from all these accidents will reach to US\$ 261.11 Million.

4. DISCUSSION:

The improved safety performance could not be achieved until there is some investment on it. Owners or management of the construction organizations remain reluctant to spend money on safety as they ignored or do not know the consequences even the financial. One of the main factors which could motivate the owner and the management of the construction organizations to spend on the safety and health related issue, that they know the costs of accidents. When the top management or the owner will have a clear idea of the costs of accidents, they will be then prepared to spend on the preventive measure. The matter is not only associated with organizations but there is also a need of awareness at government level as how much their country economy is affected by such costs which can be prevented by a small investment. One of the main factors which can help to reduce the costs of accidents in construction is to reduce the number of accidents. The reduction of accidents in construction required many steps such as training and education, compliance with PPE, accidents investigations, management commitment, inspections and supervision, and compliance with regulations. In most cases, the decision makers avoid these steps simply to control their expenditure, assuming that the accidents normally do not happens on regular basis. It can be true that the accidents may not happens regularly, however, when they happen, the cost is normally high that the cost of prevention, and this is the fact which top management negate. This is also related to the awareness of the costs of accidents – in other words, when the top management will have less awareness of the costs of accidents, they will be reluctant to spend on the matters associated with safety. This article therefore estimated the costs of accidents arising from workplace which could be useful to reflect the importance of investment to improve safety related issues in the GCC region. The GCC construction market is grooming and provides jobs to millions of peoples both locally and internationally. The rapid growth of the construction industry in GCC region have also resulted several issues including poor safety performance. In such a situation the estimate of the costs of accidents in this region may be helpful to motivate both the government and construction organizations working in this region to improve their safety performance. The estimates of the costs of accidents produced in this paper, is however, based on several assumptions due to the lack of data associated with the accidents in the region. Construction accidents can be classified in different way, for instance, based on the type of injury. Clearly, some injuries may only require first aid and other would need hospitalization for treatment. Local regulations, cost of treatment, country law, and organizations procedure are the possible factors that can influence the costs of accidents in construction. Thus, it is important that such parameters should be considered when a true cost of accident in construction is required to be estimated. Since, the cost of accident estimated in this paper used some data from related to cost from other countries, therefore, the estimates produced here should be considered with a caution to avoid any misinterpretation.

5. CONCLUSION:

Three countries among the GCC including Qatar, Oman and Saudi Arabia were selected to estimate the costs of accident. Different parameters were used to estimate these costs in this region. The average values of the cost of accidents based on the projects values in USA and UK is calculated as 7.5%. First the costs of accidents in Qatar, Oman and Saudi Arabia are calculated based on this value (~7.5%) and the current projects in these countries. The results show that the costs of accidents on



this principle is US\$ 8,808 Million in Qatar, US\$ 12,268 Million in Oman and US\$ 3005.10 Million in Saudi Arabia. In the second method, the costs of accidents are calculated on the amount paid against injuries, disabilities and deaths in Oman and Saudi Arabia. There were 75 deaths and one disability caused by work-related accidents in Qatar. The total expenditures of benefits caused by these deaths (~USD 4.31 Million) and disability (~1.37 Million), was US\$ 5.68 Million which were translated into a total cost of accident in Qatar as US\$ 205,526. The amount of compensation disbursed by the PASI in 2017 against these cases (~495) is equal to US\$ 8.16 Million or US\$ 151,135 per injury, which is considered as indirect costs of accident in Oman. The total costs of an accident in Qatar and Oman are then calculated considering the relationship between the direct and indirect cost of an accident. Based on this relationship the estimated costs of an accident in Qatar stand at US\$ 205,526; while in Oman it is standing at US\$ 415,620. The costs of accidents in Qatar (~US\$ 205,526) and in Oman (~US\$ 415,620) are nine times and 16 times more than the average costs of an accident in USA, UK, SA and AUS (~US\$ 25,450) respectively. This translates into an economic burden of US\$ 205.73 Million per year on Omani economy. The available statistics related to compensation against injuries, disabilities and deaths published by the government agency in Saudi Arabia, show that in the third quarter of 2018, a total of US\$ 13.44 Million against the disabilities or deaths caused by accidents at workplace. The total number of disabilities (~386) and deaths (~16) in the same period were 402. Thus, the indirect costs per accident which result into a disability or death can be therefore estimated at US\$ 33,433. The total costs of an accident in Saudi Arabia are estimated at US\$ 91,940. The economic burden of these accidents on Saudi economy is calculated using ratio analysis between the amounts disbursed in one quarter and the number of disabilities and death in the same quarter. This method was applied as the data for remaining quarters was not available. The total number of the accidents resulting into disabilities and deaths are therefore estimated at 2,840 per year. The total costs of these accidents ($2840 \times 91840 = 261.10$ Million) put an economic burden of US\$ 261.10 Million per year on Saudi economy. The results presented in this paper are based on some assumptions and correlation. Different countries have different systems of health care for their residents and citizens. In relation to GCC region, the government health care system is not free for expatriates, therefore construction workers in this region rely on private medical insurance. Even in some cases, such insurance is also not mandatory. Access to such data either through insurance companies or construction organizations is not available. Lack of relevant and current data related to direct and indirect costs was therefore one of the main limitations of this research. The availability of such data to establish direct and indirect cost will be helpful to derive on a more realistic costs of accident in the GCC construction. Governments of different GCC countries can play their role to ensure different data related to costs of accidents are publicly available. This will not only excel the research in the area of cost of accidents, but the results will be also more reliable and accurate.

Conflict of interest:

The Authors declare no conflict of interest.

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Factors Contributing to Contractors' Health and Safety Non-Compliance on Transnet Projects

Siyabonga Shezi, John Smallwood

Nelson Mandela University

Correspondence: john.smallwood@mandela.ac.za

The construction industry is well known as being a dangerous and risky industry compared to other industries and Transnet construction sites are not immune to these revelations. Unsafe acts and unsafe working conditions are major contributors to work related incidents, injuries, and fatalities. In South Africa, the Occupational Health and Safety Act (OH&SA) and Construction Regulations 2014 are the primary legislation that govern health and safety (H&S) in construction. However, the South African construction industry exhibits high levels of non-compliance with H&S legislation, especially the Construction Regulations.

The aim of the study is to evolve a strategy to promote contractor compliance with H&S legislation and regulations by contractors undertaking Transnet projects. In general, most contractors working on Transnet construction sites are not complying with the applicable H&S legislation and safe working procedures (SWPs).

The quantitative research methodology was adopted for this study. The study was confined to ten Transnet construction sites countrywide, and a questionnaire was circulated to Transnet projects' staff, contractors' management, and built environment professionals (BEPs) such as construction project managers (CPMs), designers, and construction H&S practitioners (CHSPs).

The study established that failing to adhere to the H&S regulations and working procedures lead to contractors' workers undertaking unsafe acts (behaviours) on construction sites. Furthermore, most contractors are failing to appoint competent personnel, either due to budget constraints, and / or unavailability or lack of competent persons in the industry.

The study concluded that a good H&S management system that defines leadership, management involvement, safe work procedures (SWP), management commitment, communication, and competence, impacts positively on project H&S performance.

Recommendations include that all project and construction personnel should share the responsibility for H&S on construction sites and key responsibilities at various stages of the project should be given to personnel with the necessary H&S competencies and capacity to control project hazards and risks.

Keywords: Competencies, Construction, Health and Safety, Transnet

INTRODUCTION

Transnet is the state-owned enterprise in South Africa responsible for ports, railway, and pipeline infrastructure, which has invested R145 billion over the past five years (2013-2018) through capital expansion and modernisation of its infrastructure. Transnet has maintained its H&S performance below 0.30 of disabling injury frequency rate (DIFR) on its capital construction projects. Most of the capital construction projects cut across the three afore-mentioned infrastructure areas.

The International Labour Organization (ILO, 2015), estimates that at least 60 000 fatal accidents occur on construction sites around the world each year, representing one fatal accident every 10 minutes.



Globally, one in six fatalities recorded occurs in the construction industry. According to the Transnet monthly H&S statistics report (Transnet Capital Projects, 2016), contractors' H&S incident statistics and records indicate that contractors working on Transnet construction sites are not complying with the applicable H&S legislation and safe work procedures (SWPs). The root causes from investigations conducted on most incidents at construction sites have all, but pointed to non-conformances by contractors (Transnet Capital Projects, 2016). It has also been identified during routine H&S observations and inspections that contractors are failing to adhere to SWPs provided to them (Transnet Capital Projects, 2016). The observations have also shown that failing to adhere to the H&S regulations and working procedures lead to contractor's workers undertaking unsafe acts (behaviours) on site.

Unsafe acts of workers, rather than unsafe working conditions on construction sites are generally the causes and major contributors of work-related incidents, injuries, and fatalities (Aksorn and Hadikusumo, 2007). According to Frittella *et al.* (2013), it was evident that chasing profit, and neglecting H&S regulations and SWPs cause more accidents that result in an injury and death in the construction industry. The report further highlighted that improving compliance with H&S regulations and SWPs has better benefits (Frittella *et al.*, 2013). The benefits include reduced costs for compensation of work-related injuries, securing tender awards, fewer work stoppages because of incidents / accidents, low staff turn-over, and an increased staff morale.

The most common unsafe acts observed on Transnet construction sites in general are, *inter alia*: workers not wearing personal protective equipment (PPE); improper lifting or handling materials; failure to follow safe work methods applicable to construction work / activities, and project delays that lead to management exerting pressure on workers to quickly finish tasks. The previous studies suggest that there is a need for change of direction in construction H&S research to identify the possible factors that influence workers' decisions (Aksorn and Hadikusumo, 2007).

The Construction Industry Development Board (cidb, 2009) states that the construction industry exhibits high levels of non-compliance with H&S legislation in South Africa, especially the Construction Regulations. At Transnet, there have not been clear H&S procedures or an H&S management system to guide and properly manage contractors, except providing them with the H&S specifications required in terms of the Construction Regulations. The H&S specification is defined as the site or project-specific document prepared by the client (Transnet) pertaining to H&S requirements related to construction work and provided to the contractor (Republic of South Africa (RSA, 2014).

Frittella *et al.*, (2013) report that construction organisations will continue to incur excessive administrative costs when H&S management is not included in project costing. H&S non-compliance by contractors is likely to subject Transnet projects to the following risks: project delays (loss of production) due to work stoppages by the Department of Employment and Labour (DEL); incidents / accidents and the resultant time spent on investigations (investigation time); penalties paid to the regulator (fines); tarnished reputation of the organisation, and escalating costs due to treatment of injuries, and working days lost through sickness or legal fees (Othman, 2011).

Continuation of contractors' H&S non-compliance at Transnet project sites led to an exploratory study conducted to determine the:

- Importance of factors contributing to the prevention of non-compliance by contractors;
- Extent to which aspects negatively affect construction H&S;
- Importance of interventions contributing to an effective H&S management system, and
- Extent to which aspects contributing to incident causation on construction sites.



REVIEW OF THE LITERATURE

Overview of H&S in the South African construction context

Compliance according to Ally and Esau (2010) cited in Windapo (2013), is the practice of abiding with applicable rules, laws, and standards. In practice, it describes a situation where the critical mass of the members of a community adheres to those rules, laws, and standards. Every construction organisation in South Africa is obliged to legally comply with the minimum requirements of the OH&SA (RSA, 1993a), which regulates and outlines what is required to achieve H&S compliance. The main function of H&S compliance is to ensure a working environment without risks to the H&S of persons that may be affected by an organisation's activities. Many organisations see compliance to the OH&SA as just another obstacle that is there to prevent them from conducting business and making profit. H&S compliance is not a once off achievement, and organisations should always seek for continual improvement to maintain a satisfactory level of compliance.

Legislation

A range of legislation and regulations impact on construction H&S. In South Africa, the occupational H&S environment, excluding the mining industry, is mainly regulated by the OH&SA (RSA, 1993a) and its regulations promulgated thereunder. There has been a lot of unsatisfactory construction H&S issues that triggered changes in the legislation. The Construction Regulations 2003 were reviewed and amended in 2014.

A key objective of the Construction Regulations, 2014 is to formalise and strengthen the over-inspection and responsibility between the parties involved in construction-related projects. The new Construction Regulations place more stringent H&S obligations on a wide range of role-players who are involved in construction work, namely the client (a person for whom work is being performed), the contractor (an employer who performs construction work), the designer (a person who prepares, checks, and approves a design, which includes an architect or engineer), and principal contractor (an employer appointed by to perform construction work). This includes closer supervision by the client and more enforcement by the DEL, with severe penalties for non-compliance.

According to the Health & Safety Executive (HSE) (2006), all stakeholders, *inter alia*, clients, employers, employees, designers, and contractors involved in the construction industry has a duty and responsibility to identify hazards and manage risks pertaining to H&S on sites and must take ownership of their part in the process. Proper planning and working collaboratively at all stages of the project will significantly reduce H&S risks and incidents / accidents on construction sites.

The Construction Regulations, 2014 require contractors to appoint a competent person to manage and supervise construction work (RSA, 2014). Most contractors are failing to appoint a competent person, either due to budget constraints (i.e. inadequate provision of H&S budget on the project), and or unavailability or lack of competent persons in the industry, especially H&S professionals, for example registered Construction Health and Safety Agents (CHSAs) and Construction Health and Safety Officers (CHSOs). The South African Council for the Project and Construction Management Professions (SACPCMP) currently has a challenge and backlog in terms of assessing and certifying H&S personnel in the project and construction industry. The Construction Regulations further require that H&S inputs should be included from inception to the closeout stage of the project. Designers are expected to consider H&S and incorporate applicable H&S standards in their designs.

Relationship between unsafe acts and accidents

Aksorn and Hadikusumo (2007) report that unsafe acts of workers are considered as major contributors to work-related accidents and injuries on construction sites. An estimated 80 out of 100 people or workers who are involved in an incident, are at fault therefor. The most cited workplace



unsafe acts involved on construction site incidents / accidents and injuries are, *inter alia*, workers not wearing PPE, improper lifting or handling materials, keeping sharp objects in dangerous locations, failure to follow SWPs applicable to construction work / activities, and project delays that lead to management exerting pressure on workers to quickly finish the project.

Theories of accident causation

Goetsch (2013) suggests that the most common contributing factors to incident / accident causation are as follows: physical hazards; environmental hazards; human factors; no H&S regulations / procedures, and poor communication within, between, and among various stakeholders such as the client's CPM, designer, Construction Manager (CM), Construction Supervisor (CS), CHSA, CHSO, and others working on a construction site.

Cost of accidents (CoA)

Most expenses related to work-related accidents are hidden, and difficult to identify when quantifying for workplace CoA. Haupt and Pillay (2015) and Stranks (2006) report that accidents represent loss in an organisation, and an economic burden to the employer, workers, and society at large. CoA are categorised into direct and indirect costs. The indirect costs are greater than the direct costs at a ratio of 3:1. Research reported on by the cidb (2009) determined the indirect costs to be 14.2 times the direct costs. The most 'painful' CoA is the loss of life, and quality of life due to work-related injury or illness (ILO, 2012).

H&S performance

In general, the construction industry is always associated with poor H&S performance because of high work-related accidents rates. Top-down management commitment must clearly be visible to workers at low levels. Leadership must lead by example. According to Agumba *et al.*, (2011), H&S performance can be broadly classified into two groups, which are lagging indicators such as incident rates, and leading indicators such as measurement of H&S climate. According to Haupt and Smallwood (2005), the most used lagging indicators are disabling (lost) workday injuries, and medical case injuries.

To improve H&S performance, Musonda *et al.*, (2012) propose a client-centred model. A client's H&S culture can positively influence contractors' and designers' H&S performance. The H&S culture of clients is embedded in their H&S management system. A good system that defines leadership, involvement, SWPs, commitment, communication, and competence, and impacts positively on project H&S performance. The H&S culture of an organisation is perceived to be the only way through which H&S performance improvement is going to be realised, because it is at the core of some of the major incidents / accidents.

Key stakeholders in terms of construction H&S

All construction personnel share the responsibility for H&S on a construction site and H&S must be a 'team sport.' The cidb (2009) states that decisions made by the team at all stages of the project affects the H&S of the entire project. It is vital that key responsibilities at various stages of the project are given to personnel with the necessary H&S competence and capacity to control project risks. In most cases, the project and construction team consist of at least the client, designer, contractor(s), H&S professionals, CSs, and others (Goetsch, 2013). The Construction Regulations (RSA, 2014) require that competent personnel are appointed in writing with the duty to manage and supervise construction work and ensure H&S compliance.

Cost of construction H&S

The cost of construction H&S is incurred to maintain a construction working environment that is safe, healthy, comply with legal requirements, implement H&S measures to prevent incidents / accidents



during construction, and improve construction site H&S conditions. The estimated cost of implementing an H&S management system on a construction site is between 0.5% and 3% of total project costs (cidb, 2009). There are financial implications related to the implementation of certain requirements of the OH&SA, and Construction Regulations on a construction project. There are costs that are incurred before and during construction phase. The cost of construction H&S begins with mandatory appointments, for example, where the Construction Work Permit (CWP) is required, the client is obliged to appoint a competent CHSA to represent her / him in managing H&S on a construction project (SACPCMP, 2013a). The contractor is mandated to appoint a full-time, or part-time CHSO, H&S representative, and H&S committee. There are other construction H&S costs that are required for the implementation and monitoring of a construction site H&S management system (H&SMS) management system, and H&S plan.

Construction H&S management system

An H&SMS is a systematic framework developed to facilitate H&S management on a construction site. Integrating an H&SMS with other existing management systems can enhance project performance, and create motivation, understanding, commitment, and awareness among construction workers (Yiu *et al.*, 2019). Many organisations have adopted an integrated management system approach, by incorporating systems such as the occupational H&S management system (ISO 45001), environmental management system (ISO 14001), and quality management (ISO 9001) into one system to manage risks holistically. The integrated approach will benefit the organisation by improving hazard identification and risk assessment, improving worker H&S, reducing the CoA, reducing construction site risks, creating better, environmentally friendly, healthy, and safer working conditions with good quality work, and acquiring global management system certification. The H&S policy, hazard identification and risk assessment (HIRA), communication, and H&S training, awareness and development are critical for a sound integrated management system capable of reducing construction incidents / accidents, and improving contractor H&S compliance, and performance in a sustained manner (Fernández-Muñiz, Montes-Peón, & Vázquez-Ordás, 2009).

RESEARCH

Research method and sample stratum

The quantitative research methodology was adopted for this study in line with the applicable requirements. The research approach took the form of descriptive research for testing objective theories by examining relationships among variables.

A structured questionnaire with 7 scaled-response questions was used to collect primary data from 120 selected Transnet and contractors' management, BEPs and CH&SPs. 63 responses were received, which equates to a response rate of 52.5%. The questionnaires were either hand delivered or sent via an e-mail to the respondents to complete. Likert scales were used to assess respondents' answers. The analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution, and a measure of central tendency in the form of a mean score (MS).

Research findings

31.0% of respondents were safety, health, environment, and quality (SHEQ) personnel, followed by project management (23.0%), engineering (including designers) (15.0%), quantity surveying (12.0%), compliance and supply chain (12.0%), and senior management (8.0%). 48.3% of respondents were female and 51.7% were male. 92% of respondents have worked in construction projects for more than a year, 59.2% more than 5 years and 33.3% for more than 10 years. The mean length of time respondents worked in construction is 8.4 years. The mean age of respondents was 40.8 years, and 96% were older than 30 years, and 15% older than 50 years. 50.8% of the respondents have an Honours degree, followed by 17.5% with a Masters degree. In summary, 82.5% of respondents have qualifications higher than a national diploma.

Table 1 indicates the importance of 35 factors in terms of contributing to the prevention of non-compliance by contractors in terms of percentage responses to scale of 1 (not important) to 5 (very important), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the factors as more than important, as opposed to less than important.

It is also notable that 24 / 35 (68.6%) MSs are $> 4.20 \leq 5.00$, which indicates that the factors are deemed to be more than important to very important / very important. H&S specification, HIRA, contractor H&S Plan and PPE amplify the reality that baseline HIRA needs to be prepared for intended construction projects. The suitable, sufficiently documented, and coherent site-specific H&S specification based on the baseline HIRA is then developed. The contractor prepares a contractor H&S plan based on the site-specific H&S specification (RSA, 2014). Daily Safety Task Instructions (DSTIs), toolbox talks, and job H&S observations further amplify the importance of planning in general, and prevention. H&S legislation, SWPs, H&S policy, and H&S instruction and rules reflect the importance of compliance and enforcement for H&S. CHSOs', CSs', and CMS' H&S competencies highlight the importance of H&S competency amongst contractor management and supervision on sites.

A further 11 / 35 (31.4%) MSs are $> 3.40 \leq 4.20$, which indicates that the factors are deemed between important to more than important / more than important - H&S management system, and H&S budget. H&S communication language, H&S suggestion programme, H&S reward / incentive scheme programme, and H&S competition amplify importance of rewarding.

Table 1: Importance of factors contributing to the prevention of non-compliance by contractors

Factor		Response (%)					MS	R
		Not Very						
		1	2	3	4	5		
H&S specification	0.0	0.0	0.0	9.5	17.5	73.0	4.64	1
Hazard identification and risk assessment (HIRA)	0.0	0.0	1.6	6.3	19.0	73.0	4.64	2
Contractor H&S plan	0.0	0.0	0.0	12.7	12.7	74.6	4.62	3
Personal Protective Equipment (PPE)	0.0	1.6	1.6	4.8	17.5	74.6	4.62	4
Daily Safety Task Instruction (DSTI)	1.6	0.0	1.6	6.3	25.4	65.1	4.57	5
H&S legislation	0.0	0.0	4.8	7.9	14.3	73.0	4.56	6
Safe work procedures (SWPs)	0.0	0.0	1.6	14.3	17.5	66.7	4.49	7
Toolbox talks	4.8	0.0	0.0	12.7	23.8	58.7	4.48	8
Supervision	0.0	0.0	0.0	14.3	23.8	61.9	4.48	9
Incident management (reporting)	0.0	0.0	1.6	15.9	17.5	65.1	4.46	10
H&S officers' H&S competencies	0.0	1.6	1.6	12.7	22.2	61.9	4.41	11
H&S policy	0.0	1.6	0.0	15.9	22.2	60.3	4.40	12
H&S inspections and audits	0.0	0.0	7.9	6.3	27.0	58.7	4.37	13
H&S training and awareness	0.0	1.6	3.2	14.3	22.2	58.7	4.33	14
Supervisors' H&S competencies	0.0	1.6	4.8	11.1	25.4	57.1	4.32	15
Construction Managers' H&S competencies	0.0	3.2	4.8	12.7	17.5	61.9	4.30	16
Project specific H&S specification	0.0	3.2	3.2	11.1	25.4	57.1	4.30	17
H&S roles and responsibilities for management	0.0	4.8	3.2	7.9	27.0	57.1	4.29	18
Tools and equipment	0.0	0.0	9.5	7.9	27.0	55.6	4.29	19
Job H&S observations	0.0	0.0	3.2	20.6	22.2	54.0	4.27	20
Housekeeping	0.0	1.6	4.8	15.9	23.8	54.0	4.24	21
Teamwork approach	0.0	1.6	6.3	15.9	20.6	55.6	4.22	22



Management involvement	3.2	3.2	4.8	12.7	23.8	52.4	4.21	23
H&S instructions and rules	0.0	3.2	6.3	11.1	25.4	54.0	4.21	24
H&S management system	0.0	4.8	7.9	11.1	15.9	60.3	4.19	25
Management commitment	1.6	4.8	6.3	9.5	25.4	52.4	4.16	26
Contractor H&S management system	0.0	3.2	9.5	9.5	27.0	50.8	4.13	27
H&S budget	1.6	3.2	11.1	9.5	22.2	52.4	4.11	28
H&S meetings	0.0	1.6	7.9	19.0	28.6	42.9	4.03	29
Site welfare facilities	0.0	4.8	6.3	15.9	30.2	42.9	4.00	30
H&S communication language	0.0	4.8	6.3	15.9	30.2	42.9	4.00	31
Visible leadership by management	0.0	9.5	4.8	14.3	22.2	49.2	3.97	32
H&S suggestion programme	3.2	9.5	4.8	25.4	27.0	30.2	3.66	33
H&S reward / incentive scheme programme	6.3	9.5	6.3	27.0	20.6	30.2	3.59	34
H&S competition	6.3	9.5	11.1	19.0	23.8	30.2	3.58	35

Table 2 indicates the extent to which 29 aspects negatively affect construction H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, respondents perceive the aspects to negatively affect construction H&S to a major, as opposed to a minor extent.

However, it is notable that 13 / 29 (44.8%) MSs are $> 4.20 \leq 5.00$, which indicates that the aspects do so between a near major to major / major extent. Unsafe working conditions, unsafe acts, and inadequate management commitment to H&S amplify the reality of aspects contributing to non-compliance and accident / incident causation on construction site. Tender evaluation and selection that does not address H&S, non-prequalification of contractors in terms of H&S, inadequate reference to H&S in contract documentation, and inadequate contractor financial provision for H&S reflects inadequate provision of H&S during procurement processes. Compressed project duration / schedule, design is incomplete when construction commences, and inadequate H&S training and awareness highlights poor planning in general and failure to prevent non-compliance through design. Inadequate monitoring of the implementation of the H&S plan through audits, and inadequate DSTIs further amplifies poor provision of assurance relative to H&S and poor planning.

A further 16 / 29 (55.2%) MSs are $> 3.40 \leq 4.20$, which indicates the aspects affect construction H&S between some extent to a near major / near major extent. Poor planning in general is largely reflected by client and contractor kick off meetings not conducted, non-communication of task based HIRAs, generic (non-specific) client H&S specifications, clients revise their requirements, and variation orders. Constructability reviews not conducted, drawings / details are revised, and design is separated from construction, highlight failure to influence H&S during the early stages of the project. Poor or inadequate H&S management systems implementation is reflected by inadequate daily site inspections, inadequate emergency response process, inadequate incident management process, progress / multi-stakeholder meetings that do not address H&S, and inadequate H&SMS. Inadequate supervision and management features in the form of inadequate site management personnel, and inadequate site management H&S competencies.

Table 2: Extent aspects negatively affect construction H&S

Aspect	Response (%)						MS	R
	Un- sure	Minor Major						
		1	2	3	4	5		
Unsafe working conditions	0.0	3.2	6.3	6.3	12.7	71.4	4.43	1
Compressed project duration / schedule	3.2	3.2	3.2	7.9	19.0	63.5	4.41	2
Tender evaluation and selection that does not address H&S	0.0	4.8	1.6	7.9	20.6	65.1	4.40	3



Aspect	Response (%)						MS	R
	Un- sure	Minor				Major		
		1	2	3	4	5		
Poor H&S culture	0.0	6.3	1.6	4.8	25.4	61.9	4.35	4
Unsafe acts	0.0	4.8	7.9	3.2	15.9	68.3	4.35	5
Inadequate management commitment to H&S	0.0	6.3	1.6	6.3	27.0	58.7	4.30	6
Non-prequalification of contractors in terms of H&S	3.2	6.3	1.6	4.8	30.2	54.0	4.28	7
Inadequate reference to H&S in contract documentation	0.0	4.8	4.8	9.5	20.6	60.3	4.27	8
Inadequate monitoring of the implementation of the H&S plan through audits	0.0	4.8	4.8	4.8	31.7	54.0	4.25	9
Design is incomplete when construction commences	1.6	4.8	7.9	7.9	15.9	61.9	4.24	10
Inadequate DSTIs	7.9	3.2	3.2	9.5	28.6	47.6	4.24	11
Inadequate contractor financial provision for H&S	3.2	4.8	4.8	9.5	22.2	55.6	4.23	12
Inadequate H&S training and awareness	0.0	4.8	4.8	6.3	31.7	52.4	4.22	13
Client and contractor kick off meetings are not conducted	1.6	7.9	3.2	7.9	22.2	57.1	4.19	14
Inadequate site management personnel	0.0	3.2	6.3	12.7	23.8	54.0	4.19	15
Non-communication of task based HIRAs	6.3	6.3	6.3	4.8	25.4	50.8	4.15	16
Constructability reviews are not conducted	3.2	6.3	3.2	6.3	39.7	41.3	4.10	17
Generic (non-specific) client's H&S specifications	3.2	6.3	3.2	14.3	23.8	49.2	4.10	18
Inadequate daily site inspections	0.0	6.3	1.6	12.7	34.9	44.4	4.10	19
Inadequate emergency response process	0.0	7.9	1.6	9.5	34.9	46.0	4.10	20
Inadequate site management H&S competencies	0.0	4.8	0.0	14.3	44.4	36.5	4.08	21
Inadequate incident management process	0.0	6.3	3.2	12.7	31.7	46.0	4.08	22
Progress / Multi-stakeholder meetings that do not address H&S	1.6	4.8	6.3	15.9	22.2	49.2	4.07	23
Inadequate H&S management system	1.6	6.3	4.8	19.0	25.4	42.9	3.95	24
Clients revise their requirements	3.2	3.2	11.1	14.3	28.6	39.7	3.93	25
Design is separated from construction	4.8	6.3	4.8	14.3	33.3	36.5	3.93	26
Drawings / details are revised	4.8	7.9	6.3	11.1	31.7	38.1	3.90	27
Variation orders	9.5	4.8	11.1	14.3	25.4	34.9	3.81	28
Contractor's cidb rating (experience)	4.8	4.8	6.3	33.3	28.6	22.2	3.60	29

Table 3 indicates the importance of aspects / interventions in terms of contributing to an effective H&SMS in terms of percentage responses to a scale of 1 (not) and 5 (very), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, respondents can be deemed to perceive the aspects / interventions as important.

It is also notable that all the MSs are $> 4.20 \leq 5.00$, which indicates the respondents can be deemed to perceive them to be between more than important to very important / very important aspects / interventions.

3 / 27 (11.1%) aspects / interventions have MSs > 4.60 , the upper part of the range, namely assessment of H&S hazards and risks, setting of clear H&S objectives and targets, and H&S training and awareness, which amplify the importance of proper planning.



The remaining 24 aspects / interventions have MSs > 4.20, the lower part of the range. Consultation and participation of workers in H&S, leadership relative to H&S, development of H&S policy, management commitment to H&S, and management review of H&SMS reflect the importance of top management involvement and decision making in terms of an effective H&S management system. Appointment of competent H&S personnel, assignment of H&S roles and responsibilities, provision of human resources for H&S, and assignment of H&S authorities amplify importance of H&S competencies, responsibilities, and authorities. Conducting of internal H&S audits, monitoring of H&S performance and measurement, conducting of external H&S audits, monitoring the development of / contributing to the H&S file audits highlights the importance of monitoring and assurance relative H&S and quality. Maintaining a project register of hazards and risks, inclusion of H&S criteria for selection of contractors, establishment of legal requirements, financial provision for H&S, plans to respond to emergency situations reflects importance of proper planning in general.

Table 3: Importance of aspects / interventions in terms of contributing to an effective H&S management system

Aspect / Intervention	Response (%)						MS	R
	Un- sure	NotVery						
		1	2	3	4	5		
Assessment of H&S hazards and risks	0.0	0.0	0.0	1.6	22.2	76.2	4.75	1
Setting of clear H&S objectives and targets	0.0	0.0	0.0	6.3	17.5	76.2	4.70	2
H&S training and awareness	0.0	0.0	1.6	3.2	22.2	73.0	4.67	3
Consultation and participation of workers in H&S	0.0	0.0	1.6	3.2	28.6	66.7	4.60	4
Conducting of internal H&S audits	0.0	0.0	0.0	1.6	36.5	61.9	4.60	5
Leadership relative to H&S	0.0	1.6	0.0	9.5	15.9	73.0	4.59	6
Maintaining a project register of hazards and risks	0.0	0.0	0.0	9.5	22.2	68.3	4.59	7
Appointment of competent H&S personnel	1.6	0.0	0.0	11.1	19.0	68.3	4.58	8
Assignment of H&S roles and responsibilities	0.0	0.0	1.6	11.1	17.5	69.8	4.56	9
Development of H&S policy	0.0	0.0	1.6	7.9	25.4	65.1	4.54	10
Inclusion of H&S criteria for selection of contractors	0.0	0.0	3.2	7.9	20.6	68.3	4.54	11
Plans to respond to emergency situations	0.0	0.0	1.6	6.3	28.6	63.5	4.54	12
Management commitment to H&S	0.0	0.0	1.6	9.5	23.8	65.1	4.52	13
Establishment of legal requirements	0.0	0.0	1.6	6.3	31.7	60.3	4.51	14
Financial provision for H&S	0.0	0.0	3.2	9.5	23.8	63.5	4.48	15
Management of H&S incidents and deviations	0.0	0.0	0.0	7.9	36.5	55.6	4.48	16
Monitoring of H&S performance and measurement	0.0	0.0	3.2	3.2	39.7	54.0	4.44	17
Assessment of H&S opportunities	0.0	0.0	1.6	6.3	39.7	52.4	4.43	18
Continual improvement of H&S	0.0	0.0	4.8	4.8	34.9	55.6	4.41	19
Compiling a project H&S 'lessons learnt' report	0.0	0.0	3.2	9.5	30.2	57.1	4.41	20
Assignment of H&S authorities	1.6	1.6	3.2	7.9	27.0	58.7	4.40	21
Management review of H&S management system	4.8	0.0	1.6	15.9	25.4	52.4	4.35	22
Conducting of external H&S audits	0.0	0.0	0.0	11.1	42.9	46.0	4.35	23
Monitoring the development of / Contributing to the H&S file	1.6	0.0	3.2	12.7	34.9	47.6	4.29	24
Control of documented information	1.6	0.0	3.2	19.0	27.0	49.2	4.24	25
Management of change	1.6	3.2	1.6	12.7	31.7	49.2	4.24	26
Provision of human resources for H&S	1.6	3.2	6.3	12.7	20.6	55.6	4.21	27



Table 4 indicates the extent to which 23 aspects contribute to incident causation on construction sites in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, respondents perceive the aspects to contribute to incident causation to more of a major than a minor extent.

It is notable that 8 / 23 (34.8%) MSs are $> 4.20 \leq 5.00$, which indicates they do so between a near major to major / major extent. A further fifteen 15 / 23 (65.2%) MSs are $> 3.40 \leq 4.20$, which indicates the aspects contribute between some extent to a near major / near major extent. All 23 aspects reflect the reality of human and workplace factors that contribute to basic causes of incidents on construction sites. Inadequate communication, unsafe working conditions, unsafe acts (violation), inadequate supervision / leadership, working under the influence of alcohol or drugs, inadequate skill level, inadequate mental state (judgement, and memory), and unsafe acts (error) are the major contributors.

Table 4: Extent to which aspects contribute to incident causation on construction sites

Aspect	Response (%)						MS	R
	Un- sure	Minor Major						
		1	2	3	4	5		
Inadequate communication	1.6	0.0	1.6	12.7	23.8	60.3	4.45	1
Unsafe working conditions	1.6	1.6	1.6	15.9	12.7	66.7	4.44	2
Unsafe acts (violation)	1.6	0.0	3.2	12.7	23.8	58.7	4.40	3
Inadequate supervision / leadership	1.6	1.6	3.2	9.5	34.9	49.2	4.29	4
Working under the influence of alcohol or drugs	4.8	7.9	1.6	6.3	19.0	60.3	4.28	5
Inadequate skill level	1.6	0.0	7.9	7.9	33.3	49.2	4.26	6
Inadequate mental state (judgement, memory, etc.)	3.2	1.6	3.2	14.3	30.2	47.6	4.23	7
Unsafe acts (error)	3.2	1.6	7.9	9.5	27.0	50.8	4.21	8
Inadequate H&S training	1.6	1.6	3.2	15.9	31.7	46.0	4.19	9
Inadequate work planning	1.6	1.6	3.2	14.3	36.5	42.9	4.18	10
Unsafe acts (voluntary)	6.3	3.2	1.6	22.2	17.5	49.2	4.15	11
Inadequate maintenance (preventative)	1.6	1.6	4.8	12.7	38.1	41.3	4.15	12
Inadequate contractor oversight	1.6	3.2	3.2	12.7	38.1	41.3	4.13	13
Inadequate physical capability (vision, hearing, etc.)	4.8	9.5	1.6	9.5	25.4	49.2	4.08	14
Inadequate engineering / design	3.2	3.2	9.5	7.9	31.7	44.4	4.08	15
Inadequate tools and equipment	1.6	1.6	11.1	6.3	38.1	41.3	4.08	16
Inadequate contractor selection	1.6	6.3	1.6	11.1	42.9	36.5	4.03	17
Unsafe (involuntary)	4.8	3.2	6.3	19.0	25.4	41.3	4.00	18
Working without authority	1.6	7.9	4.8	9.5	33.3	42.9	4.00	19
Inadequate physical condition (injury, illness, etc.)	3.2	9.5	3.2	14.3	23.8	46.0	3.97	20
Substandard PPE	0.0	9.5	6.3	11.1	25.4	47.6	3.95	21
Inadequate purchasing of materials	1.6	6.3	9.5	11.1	34.9	36.5	3.87	22
Inadequate materials' control	1.6	9.5	9.5	4.8	38.1	36.5	3.84	23

CONCLUSIONS

Given the perceived importance of factors contributing to the prevention of non-compliance by contractors, it can be concluded that HIRA, project H&S specification, contractor H&S plan, and PPE are the primary and most important factors that contribute to the prevention of non-compliance by contractors.



Given the perceived extent of aspects negatively affecting construction H&S, it can be concluded that unsafe working conditions, unsafe acts, poor H&S culture, and inadequate management commitment to H&S contribute to contractors' non-compliance and incident causation. Furthermore, exclusion of H&S during tender and procurement processes affects overall contractor H&S compliance during construction.

Given the perceived importance of aspects / interventions contributing to an effective H&S management system, it can be concluded that an assessment of H&S hazards and risks, setting of clear H&S objectives and targets, H&S training and awareness, development of H&S policy, leadership relative to H&S, and management commitment to H&S are important and can improve an H&SMS.

Given the perceived extent of aspects contributing to incident causation on construction sites, it can be concluded that adequate communication amongst construction personnel, safe working conditions and acts by workers can contribute to the prevention of incidents on construction sites. Improving skill levels of workers and testing of alcohol or drugs on construction sites will also contribute to the improvement of construction H&S and prevent unnecessary incidents.

With respect to the contribution of the study to the related body of knowledge, it should be noted that limited studies pertaining to client contractor H&S management have been conducted in South Africa, and then prior to this study, not within Transnet. The findings from the study indicate which aspects and interventions should be focused upon by all project stakeholders, including Transnet, the designers, and contractors in terms of improving construction H&S performance on Transnet projects.

RECOMMENDATIONS

H&S requirements should be incorporated into all stages of projects, from inception to project close-out. The client should prepare a suitable baseline risk assessment for intended construction work and a project / site-specific H&S specification, and contractors should prepare site-specific H&S plans based on the client's specification.

The cost of work-related incidents / accidents should be quantified and measured properly in the organisation, and management should be more visibly involved in incident investigations and ensure the implementation of the resultant recommendations.

Key responsibilities at various stages of the project should be given to personnel with the necessary H&S competencies and capacity to control project hazards and risks, and therefore, H&S training and awareness should be provided to all stakeholders on projects. The client should appoint competent CHSAs to act as a representative for them, and contractors should appoint competent personnel to manage and supervise construction work. Designers such as architects and engineers should be provided with compulsory formal H&S training.

Tender evaluation processes should improve the selection of competent contractors, and contractors should be selected based on their H&S performance and H&SMS. The client and contractor should provide adequate H&S financial provision for intended project and construction work.

Continuous training and awareness with respect to Transnet's integrated management system (TIMS) is required. Then, continuous coaching and disciplinary measures should be taken with respect to workers who constantly perform unsafe acts or violate H&S regulations, rules, and SWPs.

The client and contractor should conduct regular site inspections and audits at least once a month and compile formal reports. All project H&S documentation should be kept for records.



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Occupational health and safety factors influencing absenteeism among construction workers in Johannesburg, South Africa

Livingston Moyo¹, Shingirirai Feresu², Martha Chadyiwa², John Smallwood³

¹Empirical Academy, South Africa, ²University of Johannesburg, South Africa, ³Nelson Mandela University, South Africa

Correspondence: livington@empiricalacademy.co.za

Absenteeism among construction workers is a cause for concern in this industry. Unearthing occupational factors linked to non-attendance in this labour-intensive industry was prioritised, hence determining the relationship between occupational health and safety (OH&S) factors and absenteeism among these workers was imperative.

The study assessed if there was a statistically significant association between absenteeism and reported workplace exposures and health ailments among construction workers, to influence the effective implementation of OH&S management systems among small and medium construction firms.

A cross-sectional design was used to assess the prevalence of exposure and health outcomes for comparative analysis. A simple random sampling technique was to select research participants. The sample size of 500 participants was determined using Epi Info™ 7.2 statistical software for epidemiology. Data was analysed using the IBM SPSS™ Statistics version 26. Data visualisation tools, frequency distributions, cross tabulations, and logistic regressions were used to present and analyse data.

Research results reflected an association between absenteeism and OH&S factors. There was a probability of a small contractor employee being absent from work with an AOR of 0.34 (0.20, 0.58) and 4.04 (1.40, 11.66) for age. A correlation existed between absenteeism and workplace exposures [cement exposure 0.53 (0.30, 0.92), heat AOR of 2.60 (1.55, 4.35), and dust 1.79 (1.11, 2.90)]. An AOR of 3.49 (2.36, 5.16), 1.77 (1.05, 2.97), and 1.96 (1.12, 3.45) for workplace injuries, chronic flu, and pneumonia-related pains indicate the existence of an association between the dependent and the independent variables.

The findings of this study showed that there was a statistically significant association between absenteeism and OH&S factors. The probable association between the dependent variable and independent variables implied correlation, not causation. Further research with a focus on causative factors was recommended.

Keywords: Absenteeism, Construction worker, Health ailments, Workplace exposures

Introduction

Absenteeism among construction workers is a challenge and a cause for apprehension in the industry. Unearthing and exploring OH&S factors linked to absenteeism in small and medium contractors was the focus of this study. While much research had been conducted with respect to this issue, most studies focused on OH&S factors and employee productivity, and less on the association between OH&S factors and absenteeism. It was from this backdrop that this study sought to determine the relationship between absenteeism and OH&S factors among construction workers. The findings could influence the adoption and effective implementation of OH&S management systems among small and medium construction firms for reduced occupational injuries and disease in the workplace.

Studies pertaining to occupational health (OH) in South African construction examined H&S practices tailored towards workplace incidents in construction small and medium enterprises (SMEs) (Agumba



and Haupt, 2018). None of those studies segmented OH&S factors among small and medium entrepreneurs according to size, neither did they link them to absenteeism. In spite of those studies, the H&S in South African construction did not improve commensurately in construction SMEs (Construction Industry Development Board (cidb), 2009). It was also noted with concern that in South Africa, no study had been conducted, focused on comparing OH&S factors accounting for absenteeism by trade and contractor size. This status quo existed despite failure to report for scheduled work being perceived as a major workplace challenge in most contractors.

A study conducted by Mwanaumo and Thwala (2012) determined that exposure to health risks while working on construction projects accounted for a significant proportion of disease burden (Mwanaumo and Thwala, 2012). Unique and dynamic operations in the construction industry involving numerous uncertainties, multiple intricacies, and divergent environments, exposed employees to various risk factors (Jarkas and Haupt, 2015), a situation which could be linked to absenteeism. In addition, the above status quo indicated that H&S was still not a priority for reduced injuries and diseases on some construction sites (Vitharana, 2015). A reflection on the OH status quo among construction SMEs was beneficial to the construction SMEs, cidb, and other stakeholders, for policy-making and improved employees' wellbeing. Hence, a study of this nature was a necessity to promote the creation of a healthy and safe work environment and H&S consciousness among workers employed by construction SMEs (Vitharana, 2015; Jarkas and Haupt, 2015).

The International Labour Organization (ILO) emphasises the promotion of equality, H&S, and dignity of workers worldwide (Gonzalez-Delgado, Gómez-Dantés, Fernández-Niño, Robles, Borja, Aguilar, 2015), which included prevention from falls from rooftops, machinery failure, being struck by objects, electrocutions, exposure to silica dust, cement, asbestos, lead, welding emissions, structural collapses, and engine exhaust fumes and noise (Khashaba, El-Helaly, El-Gilany, Motawei, Foda, 2018). Kumar and Maheswari (2017) established that hazards associated with construction projects include worker tools, equipment, materials, and the workplace environment (Kumar and Maheswari 2017). The low awareness of OH issues made construction workers vulnerable to OH&S exposures in construction, amplified the importance of a study to establish the level of their awareness of occupational injuries and disease (Mwanaumo and Thwala, 2012). This called for the implementation of health risk management approaches centred on regulations, education and training, risk assessment, risk prevention, and accident analysis to achieve optimum health and wellbeing for all employees (Suárez Sánchez, Carvajal Peláez, Catalá Alís, 2017).

Methodology

This study sought to determine if there was an association between absenteeism and OH&S factors among construction workers on projects in the Johannesburg metropolitan area, South Africa.

The target population comprised of skilled, semi-skilled, and general construction workers employed by construction SMEs registered with the cidb. A self-administered questionnaire was used to collect data, and the research participants provided written informed consent before completing the questionnaires. Privacy and confidentiality were guaranteed and practiced. The purpose of the study and the instrument were explained to respondents prior to administering the research tool. In cases where a research participant did not understand a question or part of it, an investigator or data collector provided clarity without leading the respondent. After completing the questionnaire, the research participant returned the instrument to the researcher or data collector onsite.

Reliability was determined through a pilot study, which was key in reviewing the questionnaire and determining the feasibility of the research. Appropriate inferences were made based on collected evidence, to give a logical comparison between the measure in question and the outcome. Respondents included builders, painters, plasterers, electricians, carpenters, carpet installers, dry-wall

installers, plumbers, tilers, machine operators, and general workers at various construction sites. Administrators, management, and employees who were office bound on site and employees who had been employed for less than one month were excluded to confine the scope of the study to a defined population sample.

The sample size was calculated using Epi Info™ 7.2. The confidence interval was set at 95%, and the power set at 80% with the cluster sample size of 400. Considering a 25% contingency for multiple comparisons and missing data, the final sample size was 500 from an estimated population of 2 030 construction workers, populated on the Epi Info™ 7.2 statistical software. A cross-sectional study design used, estimated, and described the prevalence of absenteeism and its association with OH&S factors. Cross-tabulations were used to analyse the relationship between multiple variables (between absenteeism and non-absenteeism) among construction workers. Adjusted odds ratios were used to measure the association between workplace H&S practices and absenteeism.

Ethical clearance was sought from the Higher Degrees and Ethics Committees at the University of Johannesburg who reviewed and approved this research before data collection commenced. Letters requesting permission to interview construction workers were submitted to construction SMEs to gain access to collect data. The purpose of the study and the research participants' rights were explained. Research participants were requested to sign consent forms, specifying their voluntary participation and the right to withdraw their consent before data was submitted. Research participants were not exposed to any form of harm by participating in the study. Participants were treated equally without any form of discrimination. Completed questionnaires were assigned codes that could not be linked to any of the research participants. An environment conducive for participants to freely respond to the questionnaire was created to maintain their privacy, anonymity, and confidentiality.

Results

The study sought to quantify the frequency of absenteeism among construction SMEs' workers. Table 1 shows the socio-demographic data and incidence of workplace absenteeism and non-absenteeism among the study participants.

Table 19: Incidence of absenteeism among workers in terms of socio-demographic characteristics

Characteristic	Total		Absenteeism incidence		Non-absenteeism incidence	
	No.	%	No.	%	No.	%
Gender						
Female	52	10.4	32	61.5	20	38.5
Male	448	89.6	328	73.2	120	26.8
Age						
20 - 30 years	216	43.2	160	74.1	56	25.9
31 - 40 years	173	34.6	119	68.8	54	31.2
41 - 50 years	77	15.4	56	72.7	21	27.3
51 - 60 years	34	6.8	25	73.5	9	26.5
Country of birth						
Lesotho	17	3.4	11	64.7	6	35.3
Malawi	14	2.8	11	78.6	3	21.4
Mozambique	60	12	36	60	24	40
South Africa	244	48.8	163	66.8	81	66.8
Zimbabwe	17	3.4	11	64.7	6	35.3
Education						
College	85	17.0	57	67.1	28	32.9



Secondary school	341	68.2	252	73.9	89	26.1
Primary school	61	12.2	46	75.4	15	24.6
No formal schooling	13	2.6	5	38.5	8	61.5
Total	500	100.0	360	72.0	140	28.8

89.6% of workers were male, and 10.4% were female. 73.2% of male workers reported having been absent, compared to 61.5% of female workers. 68.2% of workers had secondary school education, 17.0% college-level education, and 12.2% had primary school education.

The researchers investigated whether there was an association between absenteeism and workplace exposures among the workers. Table 2 below presents cross-tabulations to model the relationship between workplace exposures and absenteeism based on the time spent in the presence under each condition per day.

Table 20: Incidence of absenteeism among construction workers in terms of workplace exposure

Workplace exposure	No/Yes	Total		Absenteeism incidence		Non- absenteeism incidence	
		No.	%	No.	%	No.	%
Exposure to dust	No	122	24.4	88	72.1	34	27.9
	Yes	378	75.6	272	72.0	106	28.0
Exposure to noise	No	61	12.2	41	67.2	20	32.8
	Yes	439	87.8	319	72.7	120	27.3
Exposure to heat	No	219	43.8	159	72.6	60	27.4
	Yes	281	56.2	201	71.5	80	28.5
Exposure to rain	No	279	55.8	181	64.9	98	35.1
	Yes	221	44.2	179	81.0	42	19.0
Exposure to chemicals	No	316	63.2	213	67.4	103	32.6
	Yes	184	36.8	147	79.9	37	20.1
Exposure cement	No	151	30.2	98	64.9	53	35.1
	Yes	349	69.8	262	75.1	87	24.9
Exposure sewage and dirty water	No	315	63.0	213	67.6	102	32.4
	Yes	185	37.0	147	79.5	38	20.5
Exposure to limited lighting	No	353	70.6	234	66.3	119	33.7
	Yes	147	29.4	126	85.7	21	14.3
Total		500	100	360	72	140	28

Three hundred and seventy-eight (378), four hundred and thirty-nine (439), and three hundred and forty-nine (349) construction workers who had either been present or absent from work reported being exposed to dust, noise, and cement, respectively. Of the employees who were exposed to dust, noise, and cement, 72.0%, 72.7%, and 75.1% recorded absenteeism, respectively.

Logistic regression models in Table 3 were used to present the effect of workplace exposures and hazards on absenteeism.

Table 21: Crude and adjusted odds ratios for construction workers in terms of workplace exposures

Workplace exposure	Crude Odds Ratio	95% Confidence interval	Adjusted Odds Ratio	95% Confidence interval
Exposure to dust	0.97	(0.71, 1.31)	1.79	(1.11, 2.90)
Exposure to noise	0.95	(0.68, 1.31)	0.9	(0.44, 1.87)



Exposure to heat	0.95	(0.68, 1.31)	2.60	(1.55, 4.35)
Exposure to rain	1.60	(1.08, 2.38)	0.81	(0.50, 1.30)
Exposure to chemicals	1.49	(0.98, 2.27)	1.45	(0.92, 2.30)
Exposure cement	1.13	(0.82, 1.56)	0.53	(0.30, 0.92)
Exposure sewage and dirty water	1.46	(0.96, 2.20)	1.72	(1.04, 2.84)
Exposures to limited lighting	2.26	(1.36, 3.75)	0.76	(0.40, 1.46)

Table 3 shows the probable effect of workplace exposures on absenteeism among construction SMEs' workers. The AOR indicated that there was a correlation between absenteeism and exposure to dust, heat, cement, and sewage, and dirty water. A positive correlation of 1.79 (1.11, 2.90) existed between absenteeism and dust, a positive correlation of 2.60 (1.55, 4.35) with heat, another positive correlation of 1.72 (1.04, 2.84) with sewage and dirty water, and a negative association of 0.53 (0.30, 0.92) with cement.

Manual work which characterises the construction industry exposes construction workers to several health ailments. Table 4 presents data that reflects the incidence of absenteeism and non-absenteeism that have a probable association with physical and respiratory health ailments among this populace.

Table 22: Incidence of absenteeism among construction workers in terms of health ailments

Ailment	No/Yes	Total		Absenteeism incidence		Non-absenteeism incidence	
		N	%	N	%	N	%
Workplace injury incidents	No	415	83.0	281	67.7	134	32.3
	Yes	85	17.0	79	92.9	6	7.1
Pain induced by bending	No	286	57.2	166	58.0	120	42.0
	Yes	214	42.8	194	90.7	20	9.3
Pain induced by pushing	No	301	60.2	191	63.5	110	36.5
	Yes	199	39.8	169	84.9	30	15.1
Pain induced by pulling	No	307	61.4	190	61.9	117	38.1
	Yes	193	38.6	170	88.1	23	11.9
Pain induced by lifting	No	235	47.0	137	58.3	98	41.7
	Yes	265	53.0	223	84.2	42	15.8
Pain induced by working in one position too long	No	238	47.6	145	60.9	93	39.1
	Yes	262	52.4	215	82.1	47	17.9
Respiratory ailments							
Difficulty breathing	No	244	48.8	158	64.8	86	35.2
	Yes	256	51.2	202	78.9	54	21.1
Chronic coughing	No	306	61.2	206	67.3	100	32.7
	Yes	194	38.8	154	79.4	40	20.6
Coughing blood	No	362	72.4	240	66.3	122	33.7
	Yes	138	27.6	120	87.0	18	13.0
Breathing noisily	No	316	63.2	214	67.7	102	32.3
	Yes	184	36.8	146	79.3	38	20.7
Chest pain	No	92	18.4	75	81.5	17	18.5
	Yes	408	81.6	285	69.9	123	30.1
Chronic mucus	No	278	55.6	190	68.3	88	31.7
	Yes	222	44.4	170	76.6	52	23.4
Chronic flue	No	105	21.0	83	79.0	22	21.0



	Yes	395	79.0	277	70.1	118	29.9
Pneumonia related pains	No	383	76.6	256	66.8	127	33.2
	Yes	117	23.4	104	88.9	13	11.1
Total		500	100.0	360	72.0	140	28.0

Most employees experienced absenteeism due to pain induced during various workplace activities. Two hundred and sixty-five (265) employees experienced pain while lifting equipment and material in the workplace, while two hundred and sixty-two (262) experienced some pain induced by working in one position for too long. Many construction workers reported experiencing respiratory-related ailments in the workplace. 78.9% of those that experienced difficulty breathing, 69.9% of those that reported having had chest pains, and 70.1% that had experienced chronic flue connected to their working environment, had been absent.

The association between absenteeism and health ailments among construction workers was also examined. Table 5 below presents odds ratios that seek to model the effect of workplace health ailments and on workplace absenteeism.

Table 23: Crude and adjusted odds ratios for construction workers in terms of health ailments

Characteristic	Crude Odds Ratio	95% Confidence interval	Adjusted Odds Ratio	95% Confidence interval
Physical health ailments				
Workplace injury incidents	2.88	(1.18, 7.00)	3.49	(2.36, 5.16)
Pain induced by bending	2.12	(1.21, 3.71)	0.94	(0.12, 7.35)
Pain induced by pushing	1.23	(0.75, 2.03)	0.54	(0.33, 0.89)
Pain induced by pulling	1.62	(0.94, 2.77)	1.17	(0.78, 1.76)
Pain induced by lifting	1.16	(1.74, 1.83)	0.95	(0.64, 1.43)
Pain induced by working in one position for too long	1.41	(0.75, 1.37)	0.75	(0.51, 1.10)
Respiratory related ailments				
Difficulty breathing	1.61	(1.11, 2.33)	0.52	(0.32, 0.82)
Chronic coughing	1.66	(1.11, 2.50)	8.50	(4.04, 17.88)
Coughing blood	2.88	(1.68, 4.93)	11.93	(6.06, 23.45)
Breathing noisily	1.66	(1.10, 2.51)	0.58	(0.22, 1.48)
Chest pain	1.41	(0.75, 1.37)	0.75	(0.51, 1.10)
Chronic mucus	1.41	(0.97, 2.05)	1.76	(0.95, 3.26)
Chronic flue	1.01	(0.75, 6.38)	1.77	(1.05, 2.97)
Pneumonia related pains	3.45	(1.87, 6.38)	1.96	(1.12, 3.45)

The Odds ratios in Table 5 defined the association between reported health ailments and the incidence of absenteeism among construction SMEs' workers. There is a statistically significant positive correlation between absenteeism and workplace injury incidents reflected by an AOR of 3.49 and a confidence interval (CI) of (2.36, 5.16). Furthermore, the likelihood of a construction employee being absent due to pain induced by pushing was 0.54 times with a precision of (0.33, 0.89), reflection a negative correlation. A statistically significant positive association exists between absenteeism and respiratory ailments, with an AOR of 8.50 and a CI of (4.04, 17.88) for chronic coughing, an AOR of 11.93 and a CI of (6.06, 23.45) for coughing blood, an AOR of 1.77 and a CI of (1.05, 2.97) for chronic flue and an AOR of 1.96 and a CI of (1.12, 3.45) for pneumonia-related pains. A statistically significant negative correlation also exists between absenteeism and difficulty breathing with an AOR of 0.52 and a lower value of CI of 0.32 and an upper value of 0.82.



Discussion

The researchers examined the association between OHS factors and absenteeism among construction workers in Johannesburg, South Africa. The study sampled and collected data from five hundred (500) construction workers, using a self-administered questionnaire. The quantified frequency of absenteeism among employees in construction SMEs was assessed through the association between absenteeism and demographic factors (sex, age, education, and country of birth) among these workers. Additionally, the study examined the correlation between the dependent variable (absenteeism) and OHS factors among construction workers. The findings indicate that there were more men than women working for construction SMEs, and slightly more absenteeism among the male workers.

Absenteeism was more prevalent among the 20 – 30 years category. The main reasons for workplace non-attendance were linked to both non-occupational and OH&S factors which include illness, workplace injury, stress, and fatigue. Wee et al. (2019) observed that the younger generation recorded more incidents of absenteeism due to a combination of socio-economic, physical, and mental health factors for construction workers (Wee, Yeap, Chan, Wong, Jamil, Nantha, and Siau, 2019). Most young employees in the construction industry are new entrants in the job market, with a lack of experience, commitment, responsibility, and patience, which exposed them to workplace injuries associated with absenteeism. Furthermore, unhealthy lifestyles of young employees may be a result of alcohol abuse after pay day contributed to absence incidences (Ntuli, Emuze, and Monyane, 2015).

Construction workers from seven SADC countries participated in the study. South Africans had the highest number of absenteeism followed by Zimbabweans and Mozambicans, respectively. Workplace injuries, illness, and personal responsibilities were cited as the reasons for absence from work. Notable, there was a statistically significant negative correlation between absenteeism and nationality of respondents (Mozambique and South Africa). It is possible that factors that led to employees absconding from work, (in the case of South Africans) were an indication of discontentment, with disgruntled employees communicating their dissatisfaction with management by absenting themselves (Badubi, 2017). There was a statistically significant association between absenteeism and employees with college, secondary and primary education, with higher precision for employees with a higher level of education. This observation was compatible with the perception that low educational level had an impact on H&S awareness linked to absenteeism in the construction industry. In a study for enhanced competitiveness among construction employees in Indonesia, research participants with a higher level of education had a high level of H&S awareness and H&S compliance compared to their counterparts with low levels of education (Dardiri, Sutrisno, Kuncoro, Ichwanto, and Suparji, 2017). A higher level of education corresponds to a lower rate of absence, though crude data do not provide a clear *ceteris paribus* relationship between absenteeism and educational level (Hatletveit, 2010).

The study further assessed the association between absenteeism and reported health factors among construction workers. The study found statistically significant positive correlations between absenteeism and physical and respiratory-related health ailments, respectively. A statistically significant positive correlation between absenteeism and workplace injuries was observed among SMES' construction workers. These findings reflected that construction employees were three times more likely to be absent from work due to injuries. The 118th International Conference of Labour Statisticians, of the International Labor Organization (ILO) revealed that annual occupational accidents and diseases, caused employee absenteeism for at least four working days (ILO, 2008). A statistically significant positive correlation between absenteeism and pain induced by pushing with a high level of accuracy of the AOR is consistent with the assertion by OSH WIKI (2020), which states that lifting operations performed manually inherent in the construction industry put workers at risk of injury or health symptoms causing sick leave or disability (Deroiste, Van den Broek, and Douwes, 2020). Statistics courtesy of OSH WIKI indicate that 75% of health problems reported by construction



workers were related to musculoskeletal disorders (MSDs), which led to reduced ability to perform tasks and influenced absenteeism (Hengel, and Drupsteen, 2017).

A statistically significant association exists between absenteeism and difficulty breathing, chronic coughing, coughing blood, chronic flu, and pneumonia-related pains. These findings are consistent with the results courtesy of Tavakol et al. (2017), who determined that almost all workers in the construction industry had higher exposure to crystalline silica than the threshold limit value (TLV) required by the Iranian Ministry of Health and ACGIH (0.025 mg/m³) (Tavakol, Azari, Zendehelel, Salehpour, Khodakrim, Nikoo, and Saranjam, 2017). Similarly, in a systematic review conducted by Borup et al. (2017), the researchers found that in twelve (seven cohorts, two case-controls, and three cross-sectionals) studies, between 15 and 20% of prevalent cases of chronic obstructive pulmonary disease (COPD) had been attributed to occupational exposures to vapours, gases, dust and fumes and dust at construction sites was a major challenge (Borup, Kirkeskov, Hanskov, and Brauer, 2017).

Employees from both small and medium entrepreneurs reported exposure to dust, noise, cement, rain, dirty water, and limited lighting, linked to incidents of absence from work. These findings concur with the results of Bhosale and Biswas (2015), who found that unhealthy and intolerable working conditions which existed on construction sites, affected workers' health causing them to be absent from work (Bhosale, and Biswas, 2015). There is a statistically significant positive association between absenteeism and exposure to dust, and a statistically significant negative correlation between absenteeism and cement exposure. The 95% confidence level indicates a low precision for exposure to dust and a high precision for exposure to cement. In a study on personal exposure to inhalable cement dust among construction workers, Peters et al. (2009) found that inhalable dust concentrations at the construction site ranged from 0.05 to 34 mg/m³, with a mean of 1.0 mg/m³, an average concentration for inhalable cement dust of 0.3 mg/m³ (GM; range 0.02–17 mg/m³), and levels in the ready-mix and pre-cast concrete plants were on average 0.5 mg/m³ (GM) for inhalable dust, and 0.2 mg/m³ (GM) for inhalable cement dust (Peters, Thomassen, Fechter-Rinkc, and Kromhouta, 2009).

Further, Dutta et al. (2015) observed a statistically significant association between absenteeism and exposure to heat. In a study relative to perceived heat stress in India, researchers found that 59% of labourers reported heat-related symptoms, mild to severe. (Dutta, Rajiva, Andhare, Azhar, Tiwari, Sheffield, and Ahmedabad, 2015). No ailment from exposure to sewage and dirty water showed a probability that construction employees would be absent from work due to exposure to dirt and sewage water exposure. Conversely, a study by Tiwari (2008) found that exposure to sewage was independently associated with positivity for hepatitis B virus (HBV) infection ($P < 0.001$) (Tiwari, 2008).

Conclusions

The findings of this study indicate that there is a statistically significant association between absenteeism and OH&S factors. A statistically significant correlation exists between absenteeism and socio-demographic factors, and health ailments workplace exposures. These findings require one to note that the probable association between and the dependent variable and independent variables, implied correlation, not causation. Consequently, no causality could be claimed or denied between absenteeism and OH&S factors.

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Conflict of interest

The authors declare that they have no conflict of interest

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Protecting the Image - PPE or branded workwear? A mega-project case study

Alistair Gibb; Phil Bust; Wendy Jones

School of Architecture, Building & Civil Engineering, Loughborough University, LE11 3TU, UK

Correspondence: a.g.gibb@lboro.ac.uk

ABSTRACT

High visibility workwear has become ubiquitous on most large construction sites in many countries across the world. Short-sleeved 'tabards' have been superseded on many sites by full length trousers and jackets. The main overt rationale is conspicuity for the safety of the wearer. However, it has become common practice for organisations, and sometimes projects, to use the workwear to advertise their name or corporate logo. As part of a transformational health, safety and wellbeing strategy, London infrastructure mega-project, Tideway, has gone one step further, by designing and procuring a new suite of workwear, moving away from the standard yellow or orange to red and teal. They have also developed a new type of work boot, based on snowboarding footwear. The project team's desire was to create a distinctive style and also to stimulate a positive project *belonging* as part of their health safety and wellbeing culture. However, producing a new set of workwear from scratch created some unexpected challenges for the project team. As part of a three-year longitudinal study, funded by IOSH, researchers followed the design and procurement of this transformational PPE, deriving lessons for future projects considering similar interventions. The paper draws on data from face-to-face interviews, site observations and field notes from meetings over the full three years.

KEYWORDS: Health; Safety; Wellbeing; PPE; Workwear; Mega-Projects; Vision

INTRODUCTION

Tideway is a seven-year construction infrastructure mega-project, constructing a 24km long, 7m diameter sewer tunnel along the river Thames in London as part of a plan to prevent overflows of raw sewage into the river. At peak, the workforce was more than 2000.

Lead by CEO Andy Mitchell, Tideway set out to provide transformational health, safety and wellbeing (HSW). This strategy was very influential in setting the vision and standards, and making key decisions in the planning phases of the project. One such decision was to design and procure project specific workwear and PPE (personal protective equipment) for all personnel when on site, irrespective of who their direct employer was. In particular, there was a desire to do more than just add a logo to industry-standard kit. This paper does not address the design or effectiveness of PPE as such, rather it focusses on how PPE has developed into branded workwear, and how this is driven by concerns over corporate marketing and image.

Protective workwear has been around for centuries, with the earliest examples probably being forms of armour for soldiers. "As early as the Fourth Century, the Japanese conceptualised the idea of using

iron plates strapped with leather to soldiers' and horsemen's torsos during combat to prevent injuries" (Cheung, 2013).

However, beyond the military context, images of blacksmiths in the middle ages feature heavy leather aprons to protect from the heat of the furnace and hot metal being worked. 'Donkey' jackets were originally made for workers in the late 1800s by George Key, a small bespoke tailor who was tasked with creating a coat for workers that could withstand the cold northern weather on the Manchester Ship Canal (Anon, 2020).

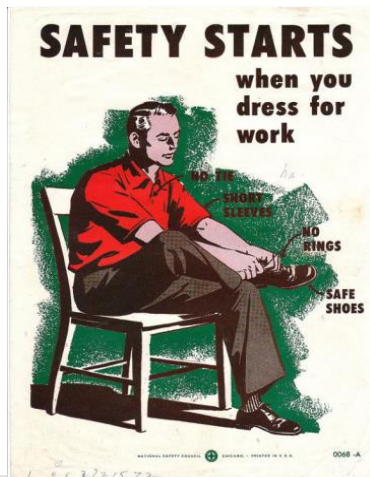


Figure 1 - Workwear poster, Chicago, 1960

In the middle of the 20th century, the importance of appropriate workwear began to be emphasised (e.g. Figure 1).

Contractor, John Laing, historically one of the largest UK construction companies (Now Laing O'Rourke), has created a very useful archive of historical construction images available at <https://HistoricEngland.org.uk>. A visual review of this archive shows that very little personal protective equipment (PPE) was worn through most of the 20th century (Figure 2), except probably wellington boots and sometimes dungarees. The ubiquitous donkey jacket in the late 1950s marked with the employer's company name being one of the earliest attempts to conspicuously brand PPE workwear (Figure 3). Note that companies like Laing



Figure 2 - John Laing Construction workers in 1949 (Source Laing Archive, 000702; 001271)



Figure 3 - Laing Branded Donkey Jackets initially with 'L' then 'LAING' (mid-late 1950s) (Source Laing Archive, 045624, 056101)

In the UK, the first specific legislation mandating the wearing of PPE was the 1989 Construction (Head Protection) Regulations. The UK's 1992 Personal Protective Equipment (PPE) at Work Act broadened out mandated PPE, emphasising that workwear must be appropriate for the conditions, must fit well and provide protection compliant with the health and safety policy. Regulation 4 of the Act states that "every employer shall ensure that suitable PPE is provided to employees who may be exposed to a risk to their health or safety while at work except where and to the extent that such risk has been adequately controlled by other means which are equally or more effective."

Apparently, high visibility (hi-vis) clothing was first used in WWII, worn to reduce the likelihood of friendly fire. However, in 1964, Scottish Rail were the first company to introduce hi-vis into the work environment following a large number of incidents – its use in the rail sector spread rapidly (Anon, 1970). Hi-vis clothing is made from fluorescent material and incorporates reflective strips.

The European standard EN471, for hi-vis clothing was introduced in 1994, revised in 2003 and extended worldwide in 2013 with the issuing of EN ISO 20471 which specifies three classes of hi-vis workwear for three levels of conspicuity (Table 1):

Table 1 – Classes of Hi-Vis clothing

Class	Visibility Level	Examples	Min background material	Min retro-reflective material
1	Lowest	shoulder-belts	0.14m ²	0.10m ²
2	Intermediate	vests, tunics	0.50m ²	0.13m ²
3	Highest	jacket with long sleeves, long trousers	0.80m ²	0.20m ²

To meet these conspicuity requirements where Class 3 visibility is required, workers need to wear a full suit of workwear, incorporating minimum amounts of reflective tape and bright background material. However, the colour of the background material does not seem to be specified.

In recent years, alongside legislative advancements, custom and practice has developed. The infrastructure sector (including tunnelling) has followed the rail industry in wearing orange PPE rather than the yellow/green PPE worn by most other construction sectors. Apparently, orange was chosen for rail to avoid yellow or green, both of which are used for train signalling (Anon, 2016).

Despite PPE being the last line of defence in the hierarchy of control, PPE clothing has become so ubiquitous that it has become almost a 'badge of office' leading to the opportunity to use it as one of the front lines of corporate image. This is particularly true for high-profile mega-projects, keen to project their image on the surrounding population along with creating a positive HSW culture. This also serves to blur the distinction between PPE to protect the wearer and uniform workwear with very different underlying motivations.

RESEARCH METHOD

The content of this paper has been developed from the findings of the three-year longitudinal research tracer study on Tideway. This longitudinal methodology was first developed by Woodward (1970) and is discussed and critiqued in detail in Fuller *et al* (2019). Four field researchers were embedded in the various Joint Venture teams through the three-year research project, each spending considerable time on site, involved in meetings, observing site practices and behaviours and interviewing key players. The full dataset included 312 observed meetings, 39 other observations, 9 focus groups, and 149 interviews. The interviews followed a general guideline of prompts focussing on issues that concerned the interviewees around the time of the interview.



The majority (n=131) of the interviews were audio recorded and transcribed; where this was not possible (n=18), extensive notes were taken instead. Furthermore, project documentation such as Works Information contracts, meeting minutes, progress reports and lessons learnt from incidents, were evaluated. These interviews, meeting notes and observations were stored in a database on NVivo and thematically coded by the researchers using a mutually agreed coding system. The researchers performed spot checks of each other's coding to ensure consistency between the three datasets. The full dataset was analysed further at the end of the data collection period by a fourth researcher who was not involved with the initial data collection. A number of key areas were identified for tracing developments across the project phases, both for the interest in the topics themselves and also using the topics to study the overall management of the project. PPE/workwear was a topic that recurred throughout the study period and was therefore identified as of valid interest.

Unfortunately, IOSH ceased funding for the seven-year project after only three years and so the full evaluation of the final outcomes has not been possible. Notwithstanding, the three-year period studied still provides a significant longitudinal perspective.

Other findings from this research have been published in a number of journal papers and also presented at previous cib W099 conferences (e.g. Gibb *et al* 2018; Fuller *et al* 2019; Jones *et al* 2020; Harvey *et al* 2020).

WHAT DID TIDEWAY DO?

Transformational context

In the early days of the project, Tideway CEO, Andy Mitchell (CBE FREng), was often outspoken about the vision of transformational HSW: “*we are going to do things very, very differently*” and “*if we can't do it safely then we won't do it at all*”. Feedback from the pre-construction phase was that there was a hierarchy of HSW levels from the basic legal requirement, through minimum standards, contractual requirements, cross-project standards agreed by all joint venture contractors and transformational. This aspirational approach was a significant incentive to keep pushing for the ‘next level’, especially during the early planning stages. Some interviewees described their frustration regarding responses to their proposals saying: “Yes, it's very good, but it's not transformational, is it?”. Researchers observed some cases of change fatigue caused by the desire to do everything ‘differently’.

From the perspective of hindsight, it would appear that such an aspirational approach can be very beneficial, particularly in the early stages, to prevent people planning to “just do what we always do”. However, as projects move into the construction phase a more pragmatic approach may be more appropriate, which may mean that some of the initial targets are moderated by the reality of the project deliverables.

Sixth US President, John Quincy Adams (1767-1848), is quoted as first saying: “It is better to have tried and failed than to have never tried at all.”

Project-specific PPE workwear

Rather than just print a logo on standard kit, Tideway chose to design and procure completely new red and teal coloured PPE workwear, eschewing both the yellow/green of building construction and the orange of infrastructure. One of the initial ideas was to choose pink, thought to make a transformational statement. However, this did not meet the conspicuity requirements.

Eventually, they decided on the Tideway brand colours and this was seen as part of producing a clear project identity and belonging. The Tideway name was included on the reflective strips as well as a 'top-pocket' logo. Furthermore, all workers on site were to wear the same clothing, irrespective of who was employing them. PPE manufacturer ARCO were commissioned to design the new clothing. Figure 4 shows researcher Phil Bust wearing the Tideway PPE workwear.



Figure 4 - Tideway PPE

However, the initiative hit a number of challenges. The design development timing was when the main Joint Ventures were tendering for the main project works and EU regulations forbade any contact with tenderers. Therefore, it was not possible to obtain any feedback from workers or the companies and their purchasing teams.

The red colour ended up being very close to the traditional orange, especially after a number of washes and fading from sunlight (Figure 5). The nature of developing a new suite of clothing meant that only a limited number of options (e.g. sizes, summer/winter variants, type of material) were produced initially. There was only one manufacturer initially, thus restricting the choices for the contractors who were not able to use their corporate suppliers with whom they had negotiated prices and delivery expectations, customer support etc.

Furthermore, the start of the main construction works was brought forward by several months in an initiative called 'stretch'. This led to a significant foreshortening of the time available to procure the clothing.

As a result of such shortcomings, the initial feedback from the frontline workers and their employers was not very positive. In order to start on time, the contractors procured standard orange PPE from their normal suppliers, embossed with the Tideway logo (Figure 6). Whilst no specific percentages of the different styles were available at the time of writing, the observed evidence from site observations and photographs is that currently a considerable number of workers are wearing the 'correct' Tideway-branded clothing, but there are still many examples of standard orange kit with the Tideway logo.



Figure 5 – Faded 'red/teal' PPE



Figure 6 – Different 'Tideway' PPE actually worn

Appropriate clothing: sensitive to gender and religion

Tideway CEO Andy Mitchell's challenging target is to employ 50% women on his staff by the end of the project. Positive early user-engagement, at least with the client staff (frontline workers were not available as mentioned earlier) led to the development of workwear that was more suited to female wearers. Sizes and proportions were designed afresh (Figure 7) . Figure 8 shows a female employee demonstrating the challenge of trying to wear male-orientated PPE. Interestingly, researchers found evidence of 'female' PPE being issued to some male workers, with the store manager claiming that it was a better fit.

There was even a prototype for pregnant women, but, whilst this was well-received in principle, concerns were raised regarding the appropriateness of pregnant women doing site work, at least, in the later stages of their pregnancy. This again raises the blur between PPE (only relevant for hazardous site work) and uniform. The researchers also observed site office cleaners wearing the full hi-vis PPE as a uniform whilst vacuuming an internal staircase.

Significant progress was made with a prototype for women whose religion required certain dress codes, in particular loose-fitting garments (Figure 9). User engagement here was very encouraging and successful, however, this was not developed further, partly due to concerns that the loose-fitting clothing may cause a snagging hazard when working with moving machinery.



Figure 7 – Tideway PPE designed for women



Figure 8 – Difficulties for women wearing male-oriented PPE



Figure 9 – PPE designed for women of Islamic faith

Innovative work boots

Site footwear has not changed for many years, except probably for the outlawing of pull-on 'rigger boots' on many sites over concerns about lack of ankle support. Unfortunately, replacing pull-on boots with lace-ups brings with it some challenges about tying and re-tying correctly, especially in cold, muddy conditions and potentially wearing gloves. It is perhaps surprising that construction PPE has not traditionally learnt much from advancements elsewhere, particularly the sport sector. By contrast, Tideway decided to commission the design and manufacture of a brand-new boot style, based on snowboard boots (Figure 10).



Figure 10 – Outlawed Rigger Boots; Snow-Boarding Boot; Tideway's Site Boot

In particular, they incorporated the turn-buckle fastening which avoided tying laces. The feedback from early trials was very encouraging although there was some anecdotal evidence of needing instructions to find out how to take the boots off!. However, similar to the PPE clothing, the project-wide roll-out of the boots was resisted by the workforce and their JV employers. Purchasers and wearers preferred to stick with styles and suppliers that they had used historically, and the high initial cost was seen as a significant barrier to take-up, especially given the transient and often short-term employment of construction site workers.

IMPLICATIONS FOR THE CONSTRUCTION SECTOR

Importance of brand image to workers and employers

The different colours in the clothing do stand-out to some extent, even if the shade of 'red' is very close to the standard 'orange'. The only similar colour scheme that the research team could find was of Belgian street cleaners in Brussels!

In the middle of the field data collection phase, the principal author overheard a conversation on the train between employees of East Midlands Trains on their way to a work conference – they were discussing the potential of Virgin Trains winning the rail franchise from EMT: *"That would be great – their uniform is so much better than ours – it looks like you are a plane crew!"* (Figure 11). However, this research found that construction worker's concern over brand image was not a significant factor in their choice of PPE. Much more important was 'fit' and 'comfort', both of which required a range of alternatives to provide a degree of choice. In fact, having a choice was considered particularly important. Cost was only an issue for employers as it is they who must provide the PPE.

There is also a tension between the image of the client and project and the corporate image of the construction organisations. It is expected that the construction organisations should outlast the temporary project organisation, in this case 'Tideway'. Therefore, it is not surprising that the construction companies may want to generate their own corporate exposure from these mega-projects. This tension was raised during the construction of the London 2012 Olympic Park, where the London 2012 and the visibility of the Games' sponsors was considered paramount.



Figure 11: Branded workwear: East Midlands Trains & Virgin Trains (Source: Company websites)

Construction, as a whole, has a poor image, both in the UK and most countries world-wide. Therefore, it would seem reasonable to suggest that wearing good quality, branded workwear may well make some (maybe most) workers think more about their own image and impact on society – A senior manager on the project commented: *“We would want to provide [full] workwear so that we know that they are wearing appropriate clothing – no offensive t-shirt slogans, no ripped jeans that could snag etc”* - but maybe this is just wishful thinking?

Pros and Cons of project-specific workwear

One of the unusual aspects of the Tideway project is that it has a large number of construction sites across central London, many of which are fairly small. Therefore, emphasising project-belonging may be very helpful for the workers as well as the project itself. There was even a comment early in the planning phase that having unique PPE would mean that the general public would recognise the brand and workers would realise that they could be identified with the Tideway project and so would behave better as a result.

In theory, PPE should be designed to be appropriate for the risks faced. Therefore, having a ‘one-style fits all’ approach in terms of conspicuity and robustness means that many employees doing lower risk tasks are wearing higher-spec kit than is required. This is certainly erring on the side of safety but may have implications for the cost of workwear across all employees and, it may be that the more robust materials required to cope with the more physical tasks may make the PPE more cumbersome for other workers.

The high turnover of workers on a particular construction site is a common feature in most countries. Therefore, providing project-specific workwear is problematic and costly. Reclaiming used workwear from workers when they leave may not be possible and issuing second-hand clothes to incoming workers is unlikely to engender the desired attitude of the new worker.

An interesting side issue is illustrated by the comment from a senior manager on one of the main Tideway sites: *“The problem with everyone wearing the Tideway PPE is that you can’t work out from a distance which subcontractor a worker is employed by – they all look the same.”*



Challenges for HSW professionals

Because of the importance of construction HSW, most mega-projects, including Tideway, employ HSW professionals well before the start of construction. In this context they play significant roles that are typically visionary by necessity (Jones *et al*, 2021). Furthermore, they may well be required to work on tasks and demonstrate skills that are not traditionally considered core to the HSW practitioner domain. In the case of the development of Tideway PPE, this included the design, development, manufacture and initial procurement of innovative clothing and footwear, including a significant amount of user-research. Office workers role playing as frontline workers is unlikely to be effective.

Mega-project challenges in delivering policy to practice

The authors have covered this topic elsewhere (Fuller *et al*, 2019) but it is worthy of a brief note here. Studies of mega-projects have emphasised their importance in terms of moving industry practice and cultures forward (e.g. London 2012: Finneran *et al*, 2012; Crossrail: Davies *et al*, 2014) HIDE). However, most of the initiatives and interventions are necessarily planned before the start of a project, and this is often when there is no access to the front-line workers or companies who will be asked to implement them (in this case to 'wear' them).

Some of the frustration experienced by project teams when the reality does not quite match the vision is explained by Fuller *et al* (2019) who argue that, on mega-projects, "change interventions will frequently:

- unfold and change over time during their adaption from plans into practice (Mintzberg, 1987);
- be changed by the people and context in which they are deployed (von Thiele Schwarz *et al*, 2016; Weiner, 2009) and;
- occur within shifting organizational and operational contexts (Johns, 2006; Nielsen & Randall, 2013)."

CONCLUDING COMMENTS

Therefore, perhaps the difficulties of delivering policy in practice just need to be accepted, so that pre-construction planners and others involved at the start of projects can still be encouraged to continue to innovate and push for better outcomes. This would be despite, in reality, that it is unlikely that their vision will be fully realised in the outworking of the construction phase.

As mentioned earlier: "It is better to have tried and failed than not to have tried at all". Furthermore, failure in this context will not be complete failure and the industry will be nudged forward to better performance, health, safety and wellbeing.

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DETERMINING THE ROOT CAUSES OF ABANDONED COMPLETED COMMUNITY-BASED HEALTH PLANNING AND SERVICE IN GHANA

Edward Nana-Addy¹, Innocent Musonda²

¹Postgraduate School of Engineering Management, University of Johannesburg, South Africa: ¹Dept of Building Technology, Sunyani Technical University, Ghana:

²School of Civil Engineering and the Built Environment; Department of Construction Management and Quantity Surveying, University of Johannesburg, South Africa:

Correspondence: imusonda@uj.ac.za

ABSTRACT

Purpose of the study: This paper evaluates the root causes of abandoned completed Community-based Health Planning and Service (CHPS) projects in Ghana.

Design/Methodology/approach: The study was conducted in four phases. These include; awareness and background knowledge of the problem, extensive literature review, development of quantitative instruments, piloting of the research instrument, data collection and analysis, interpretation, and discussions of the results. Forty-six possible root causes of abandoned completed CHPS projects were identified. Purposive sampling techniques (PST) were employed to select 20 respondents from each of the 16 regions totaling 320 respondents. The respondents identified were taken from Government officials, Consultants and End-users within the 16 regions of Ghana who were directly involved with the CHPS projects. The descriptive statistical analyses of the data were adopted.

Findings: The result identified 6 most critical root causes of completed abandoned CHPS projects. In ascending order; inadequate project selection criteria, lack of political interest, delay of project approval, un-resolved dispute, changes of priority, corruption/bureaucratic bottlenecks.

Conclusion: The quest for good health care delivery in the rural communities by the ministry of health and the Ghana health service was impeded when completed CHPS projects were left un-used. The significance of the identification of the root causes is to help government or stakeholders involved in health facilities development to execute strategies to curb health completed abandonment projects in the country to have project success.

Keywords: Abandonment, CHPS building project, Project completed, Root causes, Rural health project.

INTRODUCTION

The Ghanaian decision to adapt Community-Based Health Planning and Service (CHPS) was a delight for many rural communities. The government and donors have always prioritized the development and improvement of health care delivery in rural communities. For the ministry of health and the Ghanaian health service, it was a good initiative towards achieving good health care for the rural communities. There are many healthcare buildings which are long overdue at the operational commissioning stage. Thus, the CHPS project may meet its planned schedule and budget, these can be abandoned due to external factors such as political issues and non - provision of auxiliary facilities. Many completed, but not used rural health care building projects are scattered across the whole country. Examples include Ofankor, Tetegu, and Teshie camp two health buildings which were built at a cost of GH¢ 320,000 in the Great Accra region (Citi FM and Occupy Ghana, 2018). Some of the key ones reported by media include the University of Ghana (a \$217 million health project) and Bank of Ghana hospitals in Accra. Others were the “solar-powered medical center and Volo digital village” located in the Volta Region of Ghana (Citi FM and Occupy Ghana, 2018). Also, five (5) health care facilities constructed in the South Dayi district in the Volta region which have not been operational,



many years after they were completed. The *Auditor-General Report, 19 June 2018* provided some abandoned CHPS projects in Ghana between 2015 and 2017.

This issue of abandonment needs adequate investigation to establish the causes affecting the national economy as well as its citizenry Doraisamy, et al., (2015); Saidah, et al., (2020). Also, Ayodele and Alabi (2011) opine that a healthy economy brings growth in building constructions, while low and depressed economies result in project abandonment. The successful completion of a project rests on adequate and good planning Doraisamy, et al., (2015); Amoah-Abban,(2017), stakeholders' engagement, and provision of auxiliary facilities Aluko,(2008); Abdul-Rahman, (2013); Saidah, et al., (2020).

Moreover, studies on causes of building project abandonment in Ghana and sub-Sahara Africa, in general, have been identified but Doraisamy, et al., (2015) recommended that a thorough investigation into the whole issue of project abandonment from different perspectives be done. Hence, the objective of this paper was to explore root - causes for completed CHPS projects abandonment.

LITERATURE REVIEW

Much research on the causes of public building projects abandonment have been carried out by identifying several factors like poor risk management, leadership and management issues, user involvement/ training, and planning. Others were scope and objectives change, developer expertise, procurement and estimation of cost, and choice of methodology Doraisamy, et al., (2015); Ayodele and Alabi, (2011); Uket, (2013); Damoah, (2018). Similarly, Coverdale Organization also identified seven factors that cause project abandonment in Nigeria Uket, (2013). These factors were: poor planning, objectives changed, unclear objectives, poor estimation of resources, non-user involvement, and lack of management support. However, others were a lack of performance and monitoring criteria Ariffin, et al., (2018). Moreover, poor communication, poor costing, inappropriate skills, fluctuation in government policies, and poor documentation were identified by Uket, (2013); Doraisamy, et al., (2015); Okereke, (2017); Damoah, (2018).

Also, poor strategic planning, over-ambitious projects, project requirements which are conflicting, and political influence in establishing projects were identified by Aluko, (2008); Uket (2013). Doraisamy, et al., (2015) submitted that the lack of management support, scope change, non-user involvement, unclear business objectives, and an inexperienced project management team, were factors for project abandonment as well as financial problems, poor management control, and unresolved disputes between developers and landowners.

Olalusi and Otunola, (2012); Twumasi-Ampofo, et al., (2014); Doraisamy, et al., (2015); Uket, (2017); Mac- Barango, (2017) submitted reasons for building project abandonment to include faulty design and poor planning at the inception phase, material shortage, non-users' engagement, and non-provision of auxiliary utilities such as water, electricity, and access roads.

Similarly, in Ghana, many projects failed to deliver their intended purpose and expected benefits as they were finally abandoned Andoh, (2014); Citi FM and Occupy Ghana, (2018); Ghana News Agency, (2018: 2019), and the causes of the abandonment are poor and faulty designs, non-users engagement, change of priority, poor planning at the inception phase, poor risk management, poor quality, and communication gap amongst stakeholders. Other factors may include lack of adequate, efficient utility service such as electricity, water, road and security, disbursement constraints, political influence in establishing projects, and failure for successive regimes to continue past projects Amade, (2014); Doraisamy et al., (2015); Uket, (2017); Mac-Barango, (2017). Moreover, lack of policy continuation as occupiers of political offices changes, non-provision of lighting and security after completion, and lack of budgetary allocations for project maintenance were identified as factors responsible for project abandonment Twumasi-Ampofo et al., (2014); Amoah-Abban, (2017); Damoah, (2018). Damoah and Kumi, (2018) identified 34 factors that contribute to public projects' failure and abandonment. These include political interferences, bureaucracy, poor planning and supervision, partisan politics, lack of



top management commitment, corruption, delay in payment, starting more projects at the same time, change in government and, administration. Formally, Frimpong, et al., (2003) have identified 26 factors and group them into economic, project financing, material supply, and natural conditions in their investigation into factors that contribute to water project delays and abandonment in Ghana. Similarly, Fugar and Agyakwa, (2010) identified 32 important factors and categorized them into government action, financing, contractual relations, environmental changes, material, equipment, scheduling, manpower, and controlling techniques, in their studies on causal factors of building projects delays in Ghana.

However, Lundin, et al., (2015) submitted that factors influencing housing project abandonment include; increases in material prices, inadequate funding, variation orders, and delay in payment, these factors were traced to belief systems, cultural practices, political leadership, and partisan politics. Cultural set-up could contribute significantly to project implementation and operation failure. For instance, the Ghana @50 sanitation project was abandoned by the community at Abesim in the Bono region of Ghana after completion because it was located closer to church premises, which they deem to be a holy place in the cultural sense.

Damoah and Kumi, (2018) submitted that “when citizens are closely attached to political parties, they tend not to hold political leaders accountable for their actions; hence, political party officials can manipulate the system for their personal enrichment”, this could contribute to project’s abandonment. Also, Asunka (2016), opines that compliance with “formal rules and procedures by the public were significantly lower in districts where voters demonstrate strong commitments to partisan politics and vice-versa,” compliance to procedures and “formal rules during project implementation”, could be weak, and impacts on project implementation and operation. Also, Amoako and Lyon, (2014) submitted, “institutional bottlenecks”, within public administrations, could affect projects and program operation.

The past budget reports show that the Ghanaian government depends on donors, loans, and grants from external sources to provide infrastructure development (Budget Report, 2012), this could have an influence on project implementation since most of these external funds are attached with some policies. Twumasi- Ampofo, et al., (2014), opines that the high rate of abandonment of either completed or uncompleted projects, without official policies to revive them are the factors for more project abandonment. Also, some completed projects are not commissioned to allow for operation, others are not maintained or serviced, while others are not accessible, limiting the projects from serving their intended purpose. This study therefore, aimed to uncover the possible root causes of the Community health facilities in order to achieve a sustainable health delivery to the rural communities in Ghana.

METHODOLOGY

The study was conducted in line with “exploratory sequential mixed method design”, involving four phases. The first phase involved awareness and background knowledge of the problem. The second phase consisted of an extensive literature review. The third phase included development of quantitative instruments, piloting of the research instrument, and data collection. The final phase involved data analysis, interpretation, and discussions of the results.

The forty- six (46) root causes of completed abandoned projects were identified through extensive literature reviews and interviews. These causes were piloted with government officials, community project committee members, professionals, and practitioners in four regions in Ghana namely Ashanti, Bono, Great Accra, and Northern regions. These regions were selected purposively due to their strategic location in the country. Ashanti represents the central, Great Accra for the southern part and Bono and the Northern regions represent the Savana and the northern belts respectively. The piloting was done to authenticate the causes identified and also remove the ambiguous questions. Forty (40)



respondents took part in the pilot application. The results were not included in the final quantitative study response.

According to Blaxter et al., (2006) research data is factual data recognized as essential to validate findings of research studies. The primary data was collected from key stakeholders of government projects such as government officials involved in project selection and approval. Consultants who have registered in MMDAs were contacted, and end-users. Literature reviews, report analysis, and questionnaire surveys were the main strategies for the data collection.

The 46 identified root causes of the completed project abandoned were used to develop the questionnaire. All the questionnaire items were measured using “five-point Likert’s scale as follows: Strongly Disagree = 1”, “Disagree = 2”, “Moderate = 3”, “Agree = 4”, and “Strongly Agree = 5”.

The quantitative phase of the study was conducted on three hundred and twenty (320) stakeholders who were either project selectors, approvers, advisors, or designers responsible for government projects from the 16 regions in Ghana. A total of 20 respondents in each of the 16 regions, thus totaled ($20 \times 16 = 320$). These respondents were Planning officers, Physical planners, Heads of works, Budget officers, Presiding members, Coordinating Directors, End users, Estimators/valuers, Structural Engineers, Contractors, Architects, Environmentalists, Land Economists, Estate Managers, Quality Controllers, Facility Operation Managers, Maintenance Officers, Consultants, Project Managers, and Community Development Members.

The descriptive statistical analysis of the collected data was conducted using SPSS 21 software and Relative Important Index (RII). The Relative Important Index (RII) of 0.800 to 0.770 was considered most critical, 0.769 - 0.755 as very critical and 0.754 to 0.714 was considered critical as shown in table 1.



ANALYSIS AND RESULTS

Root Causes of Completed abandoned CHPS Projects

Table 1: Evaluation of causes of completed abandoned CHPS Projects

Variables	Government officials			Consultants			End-User			Overall		
	Mean	RII	Rank	Mean	RII	Rank	Mean	RII	Rank	Mean	RII	Rank
Inadequate project selection criteria adopted	4.01	0.801	1	3.90	0.779	4	3.94	0.788	2	3.96	0.792	1
Lack of Political interest	3.94	0.788	5	3.86	0.772	7	3.85	0.771	4	3.90	0.781	2
Delay of project approval	3.92	0.785	7	3.84	0.769	9	3.82	0.765	6	3.88	0.777	3
Un-resolved dispute	3.96	0.793	2	3.84	0.769	8	3.62	0.724	20	3.88	0.777	4
Change of priority	3.85	0.770	11	3.90	0.781	2	3.97	0.794	1	3.88	0.776	5
Corruption/ bureaucratic bottlenecks	3.86	0.772	10	3.95	0.790	1	3.53	0.706	30	3.86	0.771	6
Community interference/Culture clash/ agitation from interest group	3.93	0.786	6	3.82	0.763	12	3.59	0.718	22	3.85	0.771	7
Failure for successive regimes to continue the past project	3.83	0.766	13	3.90	0.781	3	3.71	0.741	14	3.84	0.769	8
Communication gap among stakeholders	3.79	0.758	21	3.89	0.777	6	3.91	0.782	3	3.84	0.768	9
Embarking on a project without the need assessment	3.90	0.780	8	3.83	0.765	11	3.41	0.682	41	3.82	0.764	10
Non feasibility studies	3.95	0.789	3	3.69	0.737	30	3.56	0.712	28	3.81	0.763	11
Inadequate cost control	3.80	0.759	19	3.83	0.767	10	3.76	0.753	8	3.81	0.761	12
Lack of a strategic plan to aid the operation of the projects	3.81	0.763	17	3.90	0.779	5	3.41	0.682	40	3.80	0.760	13
Lack of due process in project approval	3.82	0.764	15	3.76	0.751	19	3.68	0.735	16	3.78	0.756	14
Contractor's inability to adhere to specifications	3.84	0.768	12	3.74	0.748	21	3.62	0.724	21	3.78	0.756	15
Project providing no significant impact to the citizenry	3.94	0.788	4	3.63	0.727	35	3.47	0.694	38	3.78	0.756	16
Inadequate monitoring and evaluation by supervising organization	3.75	0.751	32	3.79	0.758	15	3.85	0.771	5	3.78	0.756	17
Lack of well-defined vision/objective of the project	3.80	0.760	18	3.80	0.760	13	3.59	0.718	23	3.78	0.756	18
Inefficient/effective legal system	3.81	0.763	16	3.74	0.748	22	3.68	0.735	17	3.77	0.754	19
Rapid Inflation	3.80	0.759	20	3.79	0.758	14	3.53	0.706	31	3.77	0.753	20
Resources constrain	3.78	0.757	22	3.74	0.748	23	3.71	0.741	15	3.76	0.752	21
Poor coordination between project management officials	3.74	0.747	36	3.79	0.758	16	3.74	0.747	12	3.76	0.751	22
Inadequate/ faulty designs	3.83	0.766	14	3.70	0.739	28	3.59	0.718	25	3.76	0.751	23
Lack of management support	3.77	0.754	25	3.77	0.755	18	3.59	0.718	24	3.75	0.751	24



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Lack of budgetary allocations for project maintenance	3.76	0.752	28	3.73	0.746	24	3.74	0.747	13	3.75	0.749	25
Lack of policy continuation as occupiers of political offices change	3.77	0.753	26	3.70	0.741	27	3.76	0.753	9	3.74	0.749	26
Poor risk management	3.75	0.750	33	3.75	0.750	20	3.65	0.729	18	3.74	0.748	27
Poor project brief	3.76	0.752	29	3.68	0.736	32	3.79	0.759	7	3.73	0.747	28
Lack of accountability by the project management	3.77	0.753	27	3.71	0.743	25	3.56	0.712	27	3.73	0.745	29
Lack of due process in contract award	3.74	0.747	35	3.78	0.757	17	3.47	0.694	35	3.73	0.745	30
Lack of maintenance policy to aid maintenance of completed projects	3.74	0.749	34	3.67	0.734	33	3.76	0.753	10	3.72	0.744	31
The effect of international economy	3.78	0.756	24	3.60	0.720	41	3.76	0.753	11	3.71	0.743	32
Project Imposition	3.87	0.773	9	3.62	0.723	37	3.24	0.647	46	3.71	0.742	33
Natural disaster/ Unforeseen event	3.78	0.757	23	3.69	0.737	31	3.38	0.676	42	3.71	0.741	34
Improper documentation/ contract agreement	3.71	0.742	41	3.66	0.732	34	3.65	0.729	19	3.68	0.737	35
Inadequate planning for the project at inception	3.72	0.744	38	3.70	0.739	29	3.47	0.694	37	3.68	0.737	36
No provision of Sanitation and wastage disposal before completion	3.70	0.739	42	3.71	0.743	26	3.47	0.694	36	3.68	0.736	37
Fluctuation in government policies	3.76	0.752	30	3.58	0.717	43	3.50	0.700	34	3.67	0.734	38
The high cost of operating the projects	3.76	0.752	31	3.63	0.727	36	3.29	0.659	44	3.67	0.733	39
Poor quality control by the regulatory agencies	3.72	0.744	40	3.62	0.723	39	3.53	0.706	32	3.66	0.733	40
Non provision of auxiliary utilities such as road and electricity before completion	3.72	0.744	37	3.62	0.723	38	3.47	0.694	39	3.66	0.731	41
Lack of adequate municipal services	3.70	0.739	43	3.62	0.723	40	3.50	0.700	33	3.65	0.729	42
Unsuitable location of the project	3.72	0.744	39	3.58	0.717	44	3.29	0.659	45	3.63	0.725	43
Misunderstanding of the work requirement	3.64	0.729	46	3.60	0.720	42	3.59	0.718	26	3.62	0.724	44
Lack of user involvement	3.68	0.737	44	3.49	0.697	45	3.32	0.665	43	3.58	0.715	45
Political interference in project objective setting	3.67	0.733	45	3.43	0.685	46	3.56	0.712	29	3.57	0.714	46

Field Study, 2020



DISCUSSION OF THE RESULTS

Most Critical Ranking Causes of Completed abandoned CHPS Projects

The results show that inadequate project selection criteria adopted for infrastructure projects was the most critical cause of completed CHPS project abandonment. This was ranked first with RII value of 0.792. Various project selection techniques are available to organizations and governments. However, failure to select appropriate ones will lead to project abandonment or failure. In executing the right project, all organizations can gain competitiveness in the market using a formal process Ahmad, (2016); Monnappa, (2020). According to Adebisi and Ojo, (2018); Damoah and Kumi, (2018); Amoa- Abban, (2017). Projects require investment in terms of resources and money, and it not able to select projects of good returns on the capital and resources invested, even as they seek to develop Magni and Marchioni, (2020). Political issues are the major factors of project abandonment. This factor was ranked second with RII value of 0.781 as the main cause of CHPS project abandonment.

Delay of project approval and un-resolved disputes have been identified by Ayodele and Alabi, (2011); Olalusi and Otunola, (2012) as factors that contribute to project abandonment. Another most critical factor of completed project abandonment was changes of priority, which was ranked fifth with RII value of 0.776. The rest of the most critical factors of completed project abandonment include; corruption/ bureaucratic bottlenecks, and community interference from interest groups which were ranked at sixth and seventh positions with RII values of 0.771 each. These results agreed with Twumasi-Ampofo et al., (2014); Doraisamy, et al., (2014); Alao and Jagboro, (2017); Damoah, (2018) who opined that change of priority was a core factor for project abandonment. Issues of corruption/ bureaucratic bottlenecks and community interference from an interest group were supported by Damoah and Kumi, (2018).

Very Critical Ranking Causes of Completed abandoned CHPS Projects

Failure of successive regimes to continue the past projects was ranked eight with RII value of 0.769, as a very critical factor for CHPS project abandonment. Communication gaps among stakeholders was also identified and ranked ninth as a very critical factor with RII value of 0.768. However, studies by (Doraisamy, et al., 2015; Damoah and Kumi, 2018) points out that poor communication among the project management team is a major factor for project abandoned.

Embarking on a project without the needs assessment was ranked tenth with RII value of 0.764, this finding is supported by Hanachor, (2012); Olalusi and Otunola, (2012); Alao and Jagboro, (2017). Inadequate cost control and non-feasibility studies obtained RII values of 0.763 and 0.761 respectively as causes of CHPS project abandonment. While lack of a strategic plan to aid the operation of the projects also scored RII value of 0.760. These results were agreed by (Hanachor, 2012; Alao and Jagboro, 2017).

Other very critical factors of CHPS project abandonment identified included; lack of due process in project approval, contractor's inability to adhere to specifications, project providing no significant impact to the citizenry, inadequate monitoring and evaluation by supervising organization, and lack of well-defined vision/objective of the project. These factors were supported by Alao and Jagboro, (2017); Amoa-Abban, (2017); Ariffin, et al., (2018). Lack of a well-defined vision/objective of the project has been identified by Ayodele and Alabi, (2011); Alao and Jagboro, (2017); Adebisi and Ojo, (2018); Damoah and Kumi, (2018) as a critical factor for completed abandoned CHPS projects. Inefficient/effective legal systems factor was ranked nineteenth position with RII value of 0.754. This factor has been confirmed by Doraisamy, et al., (2016); Alao and Jagboro, (2017) as critical factors that could hamper project success. Rapid inflation was ranked in twentieth position with RII value of 0.753. This factor was supported by Alao and Jagboro, (2017); Amoa- Abban, (2017); Adebisi and Ojo, (2018) that inflation contributes to projects abandoned. Concerning resources constraints, the result confirmed that it is a very critical cause of CHPS project abandonment with RII value of 0.752 and was ranked at twenty-first position. This result was supported by Alao and Jagboro, (2017).



The rest of the very critical factors identified in the study were; poor coordination between project management officials, inadequate/ faulty designs, and lack of management support with RII values of 0.751 each and were ranked from twenty-second to twenty-fourth in descending order. Inadequate/faulty designs was critical, and this result was similar to those obtained in several studies Adebisi and Ojo, (2018); Damoah and Kumi, (2018). They argued that classic reasons for abandoned projects are due to the lack of adequate design. lack of management support which could hamper project success according to Doraisamy, et al., (2015).

Critical Ranking Causes of Completed abandoned CHPS Projects

The causes of CHPS project abandonment which obtained RII values less than 0.750 were; lack of budgetary allocations for project maintenance which was ranked at twenty- fifth position with RII value of 0.749. This result was affirmed by the studies of Ayodele and Alabi, (2011); Alao and Jagboro, (2017), who argued that the classic reason for building project abandonment was due to the lack of budgetary allocations. lack of policy continuation as occupiers of political offices change, was supported by Doraisamy, et al., (2015); Damoah, (2018). They opined that lack of policy continuation damages project success. This factor was ranked at twenty-sixth position with RII value of 0.749. Poor risk management was ranked at twenty-seventh position with RII value of 0.748, as a root cause of CHPS project abandonment. Doraisamy, et al., (2015); Alao and Jagboro, (2017); Mac- Barango, (2017) agreed to this result in their various studies. Poor project-brief was ranked at twenty-seventh position with RII value of 0.747. Doraisamy, et al., (2015); Damoah, (2018) submitted that poor project brief was a major contributing factor for project abandonment. No provision of sanitation and wastage disposal before completion were ranked at forty-six positions with RII value of 0.714.

CONCLUSION

The identified factors will help the existing providers of CHPS projects to develop measures to solve the menace caused by these projects for communities to have such facilities operating. The significance of the identification of the root causes is to help government or stakeholders involved in health facilities development to withdraw strategies to curb health completed abandonment projects in the country to have project success.

The study suggested that project designers, selectors, approvers, and advisers should adopt adequate project selection method and have approval criteria model to improve infrastructure sustainability. It is recommended that project stakeholders and teams must commence project development with adequate planning at the inception phase. Adequacy of budgetary allocation should be provided including maintenance costs after completion.

Moreover, there is a need to engage the end-users in the project selection. Architects should also be in at the inception phase to produce detailed designs and incorporate all necessary utilities needed. The client should also provide supplementary facilities such as road, water, and electricity before the commission of the projects. Finally, new administrations should not be in a position to abandon projects initiated by previous administrations.

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OCCUPATIONAL STRESS AND SITE WORKERS' WELLBEING: A CASE STUDY OF GHANA

Emmanuel Aboagye-Nimo¹, Francisca Nai², Samuel Osei-Nimo³, Samuel Mamphey⁴

¹School of Environment and Technology, University of Brighton, UK, ^{2&4}School of Architecture, Design and the Built Environment, Nottingham Trent University, UK, ³Birmingham City Business School, Birmingham City University, UK

Correspondence: emmanimo@hotmail.com

ABSTRACT

Stress and its effect on workers' wellbeing are a concept that is well-documented in the academic sphere. The construction industry is no different and may even possess a slightly higher problem due to its macho culture. Site operatives such as skilled tradesmen often fall under the hard-to-reach category and tend to be missed out on many investigations. This could be as a result of the transient nature of their roles and time of site. Construction site workers are exposed to excessive job demands and this increases the risk of prolonged stress which adversely affects their wellbeing. Unfortunately, very little research and documented guide exists in the case of many developing economies particularly Ghana. This research aimed to investigate the elements of occupational stress that affect the wellbeing of site workers in Accra, Ghana. 20 semi-structured interviews were conducted with site workers. This was followed up with two focus group sessions. Some key themes that emerged were task-related stressors, work environment stressors and overall organisational stressors. It was identified that most stressors affected the workers' physical, social and psychological wellbeing. It was a common perception that the wellbeing of Ghanaian construction site workers needed to improve significantly. The identified stressors were widely agreed to affect the workers' productivity; a vital point that employers failed to pay attention to. This research offers some important recommendations based on relevant literature and respondents' views to aid in the improvement of site workers' wellbeing in Ghana and possibly countries bearing similarities in construction project practices.

Keywords: Ghana, occupational stress, site workers, wellbeing

INTRODUCTION

The nature and intensity of construction jobs highly influence workers' overall wellbeing and performance (Eaves et al. 2016). The irregular nature of site locations and inadequate control of operating environments renders the occupation a high risk one (Love et al. 2010; Bowen et al. 2013). The job site is transient, requiring site workers to constantly relocate during the construction period (Lingard and Francis 2004), rendering the focus on the workers' wellbeing secondary (ILO 2001). Most research on occupational health focuses on white-collar roles while overlooking site-based workers in the industry (Love et al. 2010). Such oversight can lead to the likelihood of increased fatalities, ill-health, and on-site skill shortage in the sector. There is a pressing need to address occupational stress among construction workers in developing countries particularly Ghana, especially as they are characterised by socio-economic challenges and labour-specific problems, including poor infrastructure and high unemployment levels (IFS, 2018). This paper is thus aimed at improving the wellbeing of site workers in relation to occupational stress in the Ghanaian construction industry. The key focus is on the impact of stress factors.



THE CONSTRUCTION INDUSTRY AND WELLBEING

Developing and industrialised economies are strongly dependent on the construction industry. Socio-economic factors contribute to the growth of GDP and job creation. The concept of overall wellbeing goes beyond one's state of health but necessitates a reflection of one's satisfaction with work and life (Cattell et al, 2017). Still, the industry's inherent hazards put workers' wellbeing at risk (ibid).

Dodge et al (2012) define wellbeing as when people have the support and resources, they need to meet a specific psychological, social, and physical challenge. Overall, wellbeing is based on matching resources to challenges that can affect individual stability when altered. Wellbeing is about indirect health factors that significantly impact employees' overall health and performance. The study issued by the Health and Safety Executive (HSE) (2015) concluded that construction workers are at great risk of musculoskeletal diseases, construction-related dermatitis, asbestosis. In recognition of these risks, Occupational Health and Safety programmes have been implemented in working practices to promote overall health and safety (H&S). Oswald et al (2019) point out that non-physical risks can also cause significant employee wellbeing issues.

Moreover, studies show the building industry reports a far higher incidence of suicide. The site-based employees have an alarming rate of suicide and job loss, resulting from occupational stress and the masculine culture prevalent in the sector (Turner et al, 2017). For example, some male-dominated construction environments prevent workers from expressing and dealing with harmful emotions that often harm their health and wellbeing (Houle et al, 2015). Construction work is strenuous, but diet and exercise, and sickness are all factors to consider when it comes to physical wellbeing (Lingard and Turner 2015; Fordjour and Chan 2019). Socio-cultural factors, which offer a sense of identity and attachment, also influence wellbeing.

Occupational stress in the construction industry

The definition of stress is multi-faceted. Lazarus and Folkman (1984) found that stress can reduce an individual's ability to adapt, which causes strain on the individual in certain instances. The definition of stress adopted for this study is 'a condition subjectively experienced by respondents who identify an imbalance between the demands addressed and resources available to them to counter these demands' (Bowen et al. 2014: 1). Nonetheless, some levels of stress are needed to excite, stimulate innovation, productivity, but not all (Leung et al. 2005). According to the European Agency for Work Environment (2009), workplace stress happens when employees cannot manage or handle work pressures. Thus, occupational stress is a given in the construction industry. On the other hand, managing various difficulties depends on a person's capability to handle demands at work.

Construction workers often suffer from stress (Lingard and Francis 2006). As research in developed economies such as the UK and Australia shows; high stress levels impact the workforce (Love et al. 2010; Lingard and Francis 2006). Equally, construction workers in developing countries such as South Africa and Nigeria record high stress levels (Bowen et al. 2013). This danger is high due to the lack of qualified employees and many building sites (ibid).

Ofori (2015) clarifies that contractors in their current capacities are incapable of completing projects from start to finish and require subcontractors' services to complete projects. With the high frequencies of time pressures, varying work locations and unstable work, construction workers are often prone to emotional fatigue. Leung et al (2016) highlight construction worker stressors as physical, emotional, and objective stress in nature and negatively impact job, safety, and organisational performance. These include prolonged exposure to physical and environmental threats, non-compliance with safety controls, and



organisational-level problems with training and work certainty. Stress leads to poor interpersonal relationships between working teams on site (Leung et al. 2005), 'burnout' amongst workers (Lingard and Francis, 2004) and finally, work-family conflict (Bowen et al. 2014). Hare et al. (2019) stress the importance of management-worker engagement when it comes to the improvement of workers' overall wellbeing through meaningful discussion, empowerment, trust motivation and commitment to cultural change. The benefits of such engagement are exponential.

The Ghanaian environment

The construction industry in Ghana contributes significantly to its gross domestic product (GDP) and jobs. Nonetheless, as a developing country, there are socio-economic challenges such as high unemployment and infrastructure deficit (IFS 2018). For Ghana, the construction industry's contribution to GDP rose from 5.7% in 2006 to 13.7% in 2017. It is worth noting that following the post-colonial period of Ghana's independence in 1957, the state-funded State Construction Corporation (SCC) was set up to oversee and upgrade urban and feeder roads. Due to management inadequacies and the arrival of strong/equipped private firms from Europe, the SCC collapsed in 1998 (Laryea and Mensah 2010). These private firms' have transformed and improved the industry over the last two decades. In recognition of these successes, the government founded the Building and Road Research Institute (BRRI) and Construction Industry Development Institute (CID) to study and offer strategic direction.

The construction industry in Ghana lacks comprehensive workplace H&S regulations. Physical measures can assist with general wellbeing (Leung et al. 2010). Nonetheless, the Labour Act 2003 (Act 651) bill regulating the workplace and occupational H&S rights is in effect. Despite this Act, workers' rights to safety and fair compensation in Ghana remain a concern (Donkoh and Aboagye-Nimo, 2016).

Overall, the tension generated by professional societies often hinders artisanal work in Ghana's construction industry. And finally, it must be noted that the Construction and Building Materials Workers' Union (CBMWU), which is meant to represent and protect its workers' working conditions and wellbeing, is poorly unionised and unappealing to the majority of workers. As a result, they seem to have less bargaining power in discussions for equal pay and working standards for construction workers in Ghana.

RESEARCH METHOD

A qualitative approach was adopted for the research project. The research was not aimed at arriving at generalizable results but rather the ability to shed more light on the stresses that workers experience and how it affects their overall wellbeing. It is widely accepted that variables for people's stressors vary significantly (Segerstrom and O'Connor, 2012) and this falls outside the scope of the current study.

Semi structured interviews and focus groups were the main data collection tools used. The interviews allowed individual views to be shared while the focus group sessions enabled the opportunity for collective perspectives to be explored. Data was collected from a total of twenty (20) participants in Accra, the capital city of Ghana as it is the fastest developing city characterised by many construction projects. A purposive sampling technique was utilized in selecting participants. The chosen participants helped the study in generating in-depth understanding of workers' experiences. Participants were chosen on their experience and expert knowledge. They included workers with skilled-trade occupations who offer specialised services at the construction phase of projects (see Table 1). All data from this study was collected before the COVID-19 pandemic.

Furthermore, the interviews were conducted with some site workers with artisanal skills such as masons, carpenters and exclusively for all site supervisors. Two focus groups were conducted. These were conducted on site and facilitated by selected participants who were briefed beforehand. They also used prompts provided by the research team. Since supervisors are superiors, it was essential to separate them



from the group discussions to avoid subordinates being intimidated by their presence in the group discussions. Finally, a mental health professional was interviewed to provide expert information on the wellbeing of construction workers in Ghana.

Some of the questions utilised in the interview guide included: What participants thought about wellbeing in general. Also, how they believed physical and emotional stress could affect an individual's personal/private life. They were also asked how they coped with other teams/gangs on site and finally, how they believed work stress affected their family lives.

Data was digitally recorded (with consent) and transcribed verbatim. Thematic analysis was used in the analysis process. The data was managed and analysed using QSR NVivo software. Due to ethical considerations, quotes and views shared are presented using code names. Thus, all information presented in this paper is anonymised.

FINDINGS, ANALYSIS AND DISCUSSION

The findings were analysed using themes developed from both literature and preliminary data analysis. Some of the broad themes used were stress factors, awareness of wellbeing, and measures for improvement. The participants varied significantly (see Table 1). The themes excluded personal stresses as it was assumed that these are inherent in how all other stressors are manifested in workers' (participants) experiences.

Table 1: Participants' profile

Participants	Code	Skilled Trade/ Profession	Number	Years of Experience
Exterior Installations	EI1	Glazier	1	5
Exterior Installations	EI2	Roofer	2	15
Finishing Occupation	FO1	Painter	1	7
Finishing Occupation	FO2	Tiler	1	9
Mechanical & Electrical	ME	Electrician	2	16
Plant Occupation	PO	Heavy Equipment Operator	1	11
Steel & Iron	SI1	Welder	1	14
Steel & Iron	SI2	Steel bender	1	8
Site Technician	ST	Site supervisor	2	19
Trowel Occupation	TO1	Plasterer	1	8
Trowel Occupation	TO2	Mason	2	17
Water & Sewage	WS	Plumber	2	14
Wood Occupation	WO	Carpenter	2	15
Ankaful Psychiatric Hospital	APH	Psychiatric Nurse	1	9

As highlighted in Table 1 there was a wide range of participants. Also, their years of experience varied from five (5) to 19 years. In addition to the traditional construction workers, it was crucial to include a Psychiatric Nurse from the nation's top psychiatric hospital; Ankaful. The main themes and the data analysed are presented in this section.

Stress factors

Participants general understanding of stress was explored. When asked to share their views on stress and work, many opinions were shared, including:

My work involves too much pressure and precision, that makes me not to be myself. (WO)



...if you think the operating caterpillar [excavator] is demanding [stressful], try plastering which requires standing always. (TO1)

From the responses, site workers clearly had a working understanding of stress. TO1 even went to the extent of showing how his role was more demanding [stressful] than excavator operators. It was evident that the participants were of the view that stress is inherent in their jobs. Furthermore, it is worth noting that the comment of TO1 alludes with Lazarus and Folkman's (1984) subjective appraisal of stress, which is dependent on an individual's response to events. Subsequently, what constitutes stress may vary from one worker to the other. Contrary to (Leung et al. 2005) assertion that some levels of stress, not extreme though are needed to invoke creativity and productivity, the participants perceived it to have a negative impact regardless of the degree of intensity.

Job demands for which workers have little control over, and in some cases, inadequate support as reviewed in the literature (Johnson and Hall, 1988) were considered stress factors. Stressors identified include work overload, long work hours, extreme temperature, and job insecurity. These are categorised as task stressors, environmental stressors, and organisational stressors.

Three key stressor factors were identified: task stressors, environmental stressors and organisational stressors.

Task stressors

Majority of participants identified work overload as a stressor arising from their occupation. Another stressor was related to long work hours. Also, they raised a concern about having to work at unstable hours to complete their task. These are evident in the following responses:

The work is very difficult. But sometimes if you work with big contractors, it makes work easier because they have machines like an electric saw to cut woods. (WO)

The nature of my job sometimes demands that I work at night, on weekends, and holidays. (FO2)

Work overload is related to the difficulty of the task and having a tremendous amount of work to do i.e., long hours. It is worth noting that most of the work overload was attributed to low technological equipment, such is evidenced in WO's comment.

Some respondents expressed their disappointment in having limited ability to exercise autonomy over their jobs. For others, unclear understanding as to how their task should be carried out causes them to be stressed. Some comments were:

I dislike it when I am instructed on how I should carry out something I have been doing for years. It makes me feel like a child who cannot think for himself. (ME)

Studies have shown that lack of autonomy induces stress of workers in construction (Leung et al. 2010). Given the position of site workers on project structure, which they are considered to be the least (Fordjour and Chan 2019), their understanding of projects may be limited. This affects their ability to schedule activities and procedures in carrying out tasks discretionally. Concerning unclear instructions, the situation can be attributed to the educational levels of these workers, which are generally low. This finding is consistent with (Leung et al. 2010) who found that role ambiguity that is lack of clarity to perform a task as stressor experienced by site workers.



Environmental stressors

Respondents expressed their concern about the physical environment for which workers have little control over specifically, harsh temperature, dust and unpleasant smells. Also, some identified the characteristics such as exposure to hazardous chemicals and excessive noise of on-site work as stressors.

The noise levels with machines are overbearing, but hey, the job needs to be done. (PO)

It's funny when your job is roofing, there isn't any to protect you from the sun while working. (EI2)

Working under these circumstances can induce or raise the stress levels of the workers. These findings are consistent with stressors identified by site workers (Leung et al. 2010). Indeed, unsafe physical environment significantly induce stress of workers on construction sites as they are directly involved with the actual construction phase of projects.

Another stressor that emerged was related to public perception presented by the social environment. Some participants stated that they would have loved white-collar jobs because of how people tag them with their jobs. One participant commented:

My father took me to learn apprenticeship in welding after I completed JHS. I would not have chosen this job if things were better at home. The way people look at us in this country is bad. (SI1)

The Ghanaian society gives much reverence to people with white-collar jobs and higher education. The perception is that site workers with artisanal skills are people who cannot pursue higher education because of financial hardships and poor academic performers. Therefore, site workers are of low social status.

Organisational stressors

Low pay and job insecurity were the main source of concern for all the respondents: site workers. Some complained about the lack of training programs to learn to enhance their skills to carry out jobs as a stressor. Also, participants identified unsatisfactory H&S measures to be factors that put a strain on them. These are evident in the responses obtained e.g.:

I cannot freely express some concerns. Sometimes the scaffold is not in the best shape. But in the end, man must eat so you don't have any choice than to use what is being provided. (TO2)

If you want to complain about every problem, then you will go hungry for a long time. The nature of the job infrequent, you have to maintain a good relationship with your foreman in order to secure jobs in the future. As the elders say, you do not bite the hand that feeds you. (SI2)

In relation to low salaries and job insecurity, it can be attributed to the type of employment contract as site workers are typically engaged temporarily, usually not exceeding six months on a project. Job insecurity has been found to raise the stress of workers (De Cuyper and De Witte 2007). The issue of lack of training and development can be associated with managerial competencies and financial constraints of Ghanaian contractors (Laryea 2010). Also, the type of employment contract or contract period is a contributing factor e.g., casual employment. Regarding H&S issues, the comment made by TO2 indicates that less of H&S practices are witnessed on Ghana's construction sites as opined by Kheni et al, (2007). This can partly be attributed to the harsh environment associated with contractors including difficulty to access financial loans, reduced managerial capacity, and high cost of equipment repair (Kheni et al. 2007; Laryea 2010). It subsequently translates to poor treatment of site workers, as they are under the control of contractors (HSE, 2015). In furtherance, these findings point out the aggressive management style of some contractors. For example, comments made by TO2 and SI2 indicates that their superiors or



contractors deal with an autocratic manner. This situation can produce multiple stressors for site workers as leadership powers are very influential in the workplace.

Wellbeing

The views of participants on wellbeing are directed towards positive feelings and the ability to function at an optimal level. It was mostly interpreted as having a sound mind and body and also, the absence of ill-health. Respondents were asked questions along the lines of what they considered as wellbeing. Similar to most other responses, ME simplified it as follows:

Wellbeing is about your health, living a healthy lifestyle. (ME)

Overall, it can be agreed that the participants have a general understanding of the term wellbeing. Although, they relate wellbeing to physical and mental health, Dodge et al (2012) define/deal with it as a tripartite state of physical, social and psychological resources to meet its corresponding challenges to maintain stability to cope with situations. Nonetheless, an interview with a participant from the health care sector revealed that mental health is statistically low, resulting from cases not regularly being reported notably by men.

Our culture and beliefs, especially believers of spiritual camps, makes it difficult for people to seek mental health treatment. The government should make more of an effort to increase public awareness and other stakeholders like companies should be mindful of their workers' health. (APH)

Despite mental health awareness, when probed to ask if they would seek help if the situation worsens, the majority were hesitant. This is primarily due to the "macho" culture, which does not encourage men to show their sentiments/emotions. Also, in Ghana, there is a myth attached to mental illness. Traditionally, it is believed that some element of madness still exists in people who have sought mental health treatment in the past. This finding may be consistent with studies that poor mental health is a significant problem for the construction industry (Love et al, 2010; Oswald et al, 2019).

It was imperative to explore the respondents' general understanding of stress and wellbeing before exploring the interplay between both concepts.

Stress and Wellbeing

Based on the tripartite system developed by Dodge et al (2012), stress and wellbeing are being explored under the following areas: physical, social and psychological dimensions.

Stress and physical wellbeing

Some participants mentioned they had been diagnosed with diseases, including musculoskeletal disorder due to the demands of the job. Others have a hearing impairment because of excessive noise identified earlier. Other effects of stressors on physical wellbeing were related to fatigue and skin problems. A couple of the comments received were:

I have developed a skin problem. At first, I did not understand where it came from, but after visiting the hospital, the doctor said it is as a result of working with cement. (TO2)

My wife has to massage me every time I close from work. (SI2)

Although it is normal to be exposed to hazardous substances on construction sites such as cement, the inadequacy of safety equipment and measures can cause serious illness, including skin problems (see HSE, 2015) as revealed by TO2. This can be traced to inadequate H&S which some identified as stress factors. Studies have shown that an increased level of vulnerability to physical illness affects wellbeing. Laryea and Mensah (2010) emphasise that PPE must be considered as a control measure to mitigate site workers risks



of injury and accidents. As for fatigue/tiredness, while it can be associated with stressors such as work overload when experienced frequently is not a good impact on physical wellbeing. Getting a massage every time after work as expressed by SI2 is an indication of muscle strain. While feeling pain is usually due to job demands/requirements, extreme activities such as bending, and movement can negatively affect one's physical wellbeing. Musculoskeletal disorders are a major cause of functional impairment and disability among site-based workers (HSE, 2015). The link between stress and physical aspects of employees' wellbeing in the construction industry has been well established in research (Lingard and Turner 2015).

Stress and social wellbeing

Workers described how time pressures cause conflict with their colleagues at the workplace. In some instances, relationships have gone sour by other stressors such as inadequate working tools and equipment. The comment below is an example:

There have been times where I have had to argue with people on the job because I felt too much pressure to complete my task on time. Recently, I got into an argument with another plasterer over a power trowel, which we all use for our various work. (TO1)

There is an indication that stress impairs social relationships among colleagues. With regards to workplace relationships, it causes inter-role conflict among workers. Poor attitudes which affect relationships its colleagues may have emanated from role ambiguity and inadequate working tools identified earlier. Nonetheless, Lingard and Francis (2004) suggest that relationships with colleagues' help reduce the negative effects of stress. Also, during the interview, a participant disclosed that he does not relate well with his kids because he spends all of his time at work. He further commented:

Sometimes I spend five days or more on-site before going home due to travelling long distances. (FO2).

Another said:

I have lost the close relationship I had with someone who used to be my best friend as a result of this job. The situation was that I could not attend his wedding because I was busy at work. At that time, I needed to make more money which I still do as the job does not come regularly. (ST)

As construction workers typically work long hours and sometimes at unstable hours to meet tight deadlines, this interferes with their non-work life such as commitments with friends and family. Studies have shown that long work hours affect work-life balance. For example, Lingard et al. (2010) found that increased working hours reduces one's capacity to complete tasks at work and home as well as a satisfaction to balance work-life activities. In respect of time with family, in recent times men take an active part in raising the family, unlike before when it was traditionally the responsibility of women. So, spending insufficient time with them affect the parent-child relationship. Moreover, regarding FO2's comment, Cattell et al (2017) found that excessive travel time was the most severe problem affecting work-life balance of employees in the construction industry. Therefore, managing work-life balance is crucial to the wellbeing of since majority of hours/time are spent at the workplace.

Stress and psychological wellbeing

Psychological impacts that came up were associated state of happiness and having a sense of purpose. In some instances, they expressed their worries about their job and sleep disorders was also prevalent in their responses.

Hmmm, most times my job makes me feel worried. (PO)



This indicates that workers are not fully satisfied with their jobs. Job satisfaction and job security are high contributors to wellbeing levels. Studies have found that job satisfaction has a positive impact on the psychological wellbeing of workers (Cattell et al, 2017). Regarding rest, some attributed it to unstable working hours, whereas others related it to long work hours. Fordjour and Chan (2019) opined that good sleeping patterns reduce negative moods to enhance psychological conditions.

It is disturbing when you go to bed to sleep, only for you to start thinking about how to get your next job to keep you going, especially in times when the current contract is about ending. (EI1)

The above comment indicates that there is a sense of frustration. The feeling of uncertainties toward the job creates emotional exhaustion. This may be consistent with De Cuyper and De Witte (2007) assertion that job insecurity of temporary workers is more directed towards life satisfaction and self-rated performance than the attitude towards job.

It is sad when the jobs we do are important, yet people in this country do not give us the respect we deserve. This attitude is bad; it does not help the nation and us as a whole. (MI)

The poor public perception had affected many workers adversely. They felt their work did not have a significant contribution to society. Some participants had cultivated the habit of drinking from working in the industry as it is perceived to free them from troubles encountered at work. Others also believe that strong alcoholic drink enables them to perform tasks without having to feel much of the workload. Arguably, the drinking culture can be connected to lifestyle health risk factors (Osei-Nimo and Kyaruzi, 2015). Furthermore, it can be triggered or intensified by the work environment. Lingard et al. (2010) emphasise that the way construction work is organised influences individual behaviour impedes the health of blue-collar workers. This finding confirms with Fordjour and Chan (2019), revealing alcohol intake is one of the top lifestyle indicators that affect the psychological wellbeing of construction trade workers in Ghana. Excessive intake of alcohol does impair one's ability to make sound decisions can influence your mental functioning capability. However, this study did not uncover workers' developing suicidal tendencies due to work stress as found by Turner et al (2017). This may be attributed to the collectivism cultural approach and concurs with Kheni et al (2007) that family and collective value system influences the health and wellbeing of workers within the Ghanaian construction industry.

Current work support systems

Despite the stress participants experience, the respondents admitted receiving some support from work which to some extent helps to reduce the impact of their wellbeing. In response to the question "how do you get support from work?", participants revealed the following:

If we are fortunate, the contractors provide a van to transport us to sites in remote locations. (WS)

Sometimes the foreman can give you a loan in times of financial hardship, that is if there is a long-term and good personal relationship between him and me. (TO1)

From the responses, there is an indication that support given to these workers are inadequate and irregular. The support they describe are more related to welfare and not their general wellbeing. Effective support depends on the managerial competency/policy or discretion of their employers. The transient nature of construction work may also affect how committed some of these managers are to the 'casual' workers. Several researchers have indicated that workplace support helps workers cope better (Love et al. 2010). In line with TO1's comment, the issue of poor salaries was also discussed earlier as an organisational stressor.

However, social support from supervisors helps to mitigate the adverse effects of stress and improve wellbeing (see Cattell et al, 2017)



CONCLUSIONS AND RECOMMENDATIONS

This paper has explored occupational stresses experienced by site workers in Ghana. The qualitative study was conducted in the capital city, Accra. The research focused on different forms of stressors namely, task stressors, environmental stressors and organisational stressors.

The study recommends the formation of an association explicitly designed for the skilled trade site workers in the Ghanaian construction industry. This association would then aim to provide and coordinate activities to promote the welfare and professional development of the workers. Training and development are of significance to reducing the stress that the site workers experience. This can also foster effective coping strategies to help mitigate the adverse effects of occupational stress on-site workers wellbeing and an even superior outcome with human developments.

The CBMWU, if managed effectively, can encourage the majority of skilled trade workers and even casual workers to join willingly. This will increase their numbers to enhance collective bargaining and negotiations to protect the interest and welfare of its members. This can address the issues of low salaries and compensation and benefits packages, including health care insurance, to reduce health-care expenses, particularly with illness associated with occupations of the site workers. Finally, the poor public image of the industry can be improved by all stakeholders making a positive change. This can also be supported by government bodies including the Ministry of Labour and Employment. Well-structured reporting mechanisms, effective management and leadership styles, and highly motivated workforce can enhance the industry considerably.

Future research projects must identify barriers that are preventing government policies developed to improve the Ghanaian construction industry and how these can be eliminated.

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Rethinking Construction Health and Safety Legislation Compliance: Lessons Learnt from COVID-19 – Pilot Study

Mohlomi T. Raliile¹, Theo C. Haupt², Mariam Akinlolu²

¹Faculty of Natural & Agricultural Sciences, University of the Free State, Bloemfontein, South Africa,

²Faculty of Engineering, Mangosuthu University of Technology, Durban, South Africa

Correspondence: mohlomiraliile@gmail.com

ABSTRACT

Despite numerous attempts to enforce construction health and safety legislation, low levels of compliance with health and safety requirements and high rates of accidents continue to exist in the construction industry. The far-reaching impact of the novel coronavirus has spawned the attention of international and national regulatory bodies and has led to the promulgation of emergency legislations both temporary and permanent. This study aims to identify lessons learnt from the COVID-19 pandemic to rethink the significance of health and safety legislation. The study further identifies how these changes have improved the overall safety landscape on construction sites. A quantitative method of data collection was adopted, and data were analysed using IBM Statistical Package for Social Sciences (SPSS) version 25. Descriptive and inferential statistics were used to analyse the data collected. The sample size for the study was 21 contractors in the region of Kwa-Zulu Natal province in South Africa. This is a pilot study which forms part of an ongoing empirical research. The study reveal that construction companies are conducting COVID-19 risk and mitigation plans, detailing the implementation plans for the safe re-activation of construction sites and the industry. It is incontestable that the pandemic has succeeded in probing the alertness, readiness and commitment of construction stakeholders as they are obliged to protect, respect and fulfil the rights to health of their workers. Although there are challenges regarding the susceptibility of the industry to the consequences of COVID-19 such as contractual obligations, additional provisions, pricing strategies and supply chain changes; the rapid response to the pandemic by construction stakeholders is unprecedented and commendable. It is hoped that after the pandemic, contractors will maintain the level of commitment and compliance with health and safety legislation in pursuing the full realisation of the health and safety of their workers as a do or die situation.

Keywords: COVID-19, Compliance, Construction, Health and Safety, Legislation

INTRODUCTION

The global construction industry is a sector where safety has reached a plateau that still accounts for many accidents, lost working days, and a high fatality injury rate (Health and Safety Executive (HSE), 2019). The fatality rate in South Africa is estimated at 25.5 per 100,000 workers (Construction Industry Development Board (CIDB), 2009). Construction accidents and injuries can be prevented through the development of health and safety legislation (Adeyemo and



Smallwood, 2017). The primary objective of occupational health and safety legislation is to prevent accidents and improve workers wellbeing through effective implementation of proper legislation (CIDB, 2009). The South African construction industry has less than 50% rate of compliance with health and safety requirements with unacceptably high rates of incidents because of poor safety culture (CIDB, 2016).

Despite government and trade union efforts, accidents continue to occur on construction sites due to contractors' lack of adherence to safety (International Labour Organisation (ILO) (2011)). Predominantly, more emphasis has been placed on safety than health when dealing with construction health and safety matters (Raliile and Haupt, 2019). Little to no coherence between compliance and the impact of legislation is seen, as contractors are not implementing all aspects of construction health and safety legislation to improve the health of workers (ibid). Primarily, contractors comply with legislation to satisfy the requirements of the Department of Labour or Department of Public Works (ibid).

The Covid-19 pandemic has presented numerous challenges to the construction industry such as delays; site closures or restrictions; labour issues because of exposure to the virus, illness, and quarantine; new health and safety protocols such as on-site screenings; supply chain issues and subcontractor issues (Giles et al., 2021). In construction, safety considerations pre-Covid-19 were mostly focused on serious incidents (Horsnail and Williams, 2020). However, in response to the pandemic, closure of businesses resulting from the inability to work safely without risk of exposure to the coronavirus, clients and contractors have implemented designs that enable social distancing and regular disinfecting of facilities (ibid).

The Covid-19 pandemic has compelled the construction industry to rethink the health and safety landscape to protect the lives of workers (Stiles et al., 2020; Jones et al., 2020). The pandemic has shown to a degree the impacts of international cooperation working together to curb the spread of Covid-19 by promptly implementing emergency legislation to protect human life (Sekalala et al., 2020). Therefore, this paper seeks to reflect upon the lessons which the construction industry could learn from the pandemic in order to protect workers not only from the pandemic but also from the impending health and safety related issues. The realisation is presented by the early response to adapt emergency legislation and to draft industry specific requirements for the safe reopening of construction activities. Compliance in this regard has been observed as the thread against contracting the virus is a matter of life and death.

Literature Review

Numerous studies have reported the urgent need to accelerate problem solving with regards to the challenges presented by Covid-19 (Marsh et al., 2021). Quick learning and the adoption of new operation protocols under the pandemic presents vast opportunities to gain new insight from shared learning and this experience could further influence shortcomings in construction health and safety (ibid). There is consensus among industry stakeholders that the Covid-19 crisis has enabled sustainable practices within construction industry, and this should be used as a catalyst towards positive change (Megahed and Ghomien, 2021). It has also been demonstrated that fewer safety incidents have been report, although this may be attributed to fewer workers on site and the notion that workers have to think more cautiously about activities which were



second in nature previously (Caminsky, 2021). Some contractors have issued new safety controls on all their sites which engages all works actively in the consideration of safety (Marsh et al., 2021).

Americas (2021) reported that with safety as a basic principle, emerging workplace trends could enable a resilient workplace post-COVID-19. Furthermore, the authors contend that when evaluating the reopening of sites, contractors should consider under safety and health; the requirements which must be put in place to protect workers and visitors against major risks, the necessary steps needed to support and promote healthy sites and workers lifestyle, and also, to ensure that workers' safety is paramount and that the "new normal" will encompass the development and implementation of comprehensive and cost-efficient workplaces that keep workers healthy (ibid).

Construction sites had to adhere to Covid-19 protocols such as for example, social distancing, implementing new hygiene and personal protective equipment (PPE) methods, and accommodating working from home for non-essential front-line workers (Stiles et al., 2020). The importance of hygiene, health and safety has never been clearer (ibid). In support of this view, since COVID-19, there has been a rapid and general change of construction site safety, health, and hygiene, relying on management to issue clear instructions and resources, as well as ensuring that the necessary protocols during COVID-19 are observed on all construction sites (ibid). Therefore, it is thought that the nature of the pandemic, which has affected the society, has helped to push through change in management perception, acceptance, and implementation of new measures at a faster rate than is normally experienced with other construction health and safety initiatives (ibid).

In response to the Covid-19 pandemic, the South African Department of Employment and Labour issued guidelines on how to deal with the pandemic at workplaces (C19 OHS, 2020). The guidelines were issued on the 17th of March 2020 shortly after the first Covid-19 case was reported on 5th of March 2020 (ibid). Under the new guidelines, the Department of Employment and Labour appealed to employers to use the recommendation of the Occupational Health and Safety Act 83 of 1993 (C19 OHS, 2020; OHSA, 1993) in particular the Hazardous Biological Agents Regulations governing workplaces in relation to Coronavirus Disease 2019 caused by the SARS-CoV-2 virus. Although OHSA necessitates employers to evaluate and update risk assessments regularly, the new threat presented by COVID-19 is undoubtedly recognisable and the primary measures to minimise the risk are now well known. The objective of conducting risk assessments in relation to COVID-19 is to deliver specific focus on COVID-19 and apply the measures mandated by the Directive to specific working environments considering the Risk Assessment Guides published the National Department of Health (C19 OHS, 2020).

The construction industry is a highly regulated environment and the key legislation governing the industry in South Africa are Occupational Health and Safety Act no 85 of 1993 (OHSA) and the Construction Regulations (CR) 2014 (OHSA, 1993; CR, 2014). Moreover, several employer federations have their own occupational health and safety committees constantly advising members on health and safety related matters. In addition, contractors employ permanent Health and Safety Officers on construction sites to monitor compliance with regulations on site



and when entering the sites. The Construction COVID-19 Rapid Response Task Team (CC19RRTT) was convened on the 18th of April 2020 with a specific mandate to put additional measures in relation to reopening of sites during the pandemic such as the entire value chain covering suppliers, manufacturers, built environment professionals and contractors to ensure the health and safety of workers on site (CC19RRTT, 2020). The necessity for this kind of response has never been more desperate. The damage to firms caused by Covid-19, together with the threat to close non-compliant companies has left a desperate need for better health and safety management on construction sites (ibid).

In the United Kingdom (UK) the emergence of the pandemic has made it vital to urgently develop viable occupational health system essential for the construction industry to be compliant and operate under the new normal (Jones et al., 2019). The rapid response to health and safety-related changes has demonstrated to both management and front-line workers what is achievable when priority is given to health and safety (ibid). Therefore, the lessons learned could benefit health and safety improvement in the future. Health and hygiene have often been overlooked in construction; however, Covid-19 presented an opportunity to accentuate the importance of general hygiene practices therefore, giving impetus to more consideration for behavioural changes in relation to health post-pandemic (Jones et al., 2020; C19 OHS, 2020). It is thought that Covid-19 has also spawned some ad-hoc behaviours that are developed by the workers.

Reports from studies conducted in the UK identified Covid-19 risks on all construction sites were well managed and that workers felt safe; workers were more comfortable to return to work, and thankful about the efforts made to keep them safe (Jones et al., 2020). On the contrary, some respondents attested that COVID-19 risk management was poor in some parts of the construction industry and that there was little evidence of changed risk, compared to pre-COVID-19 (ibid). However, the reasons identified by most respondents as to why risk might have been lower were cited; earlier and more detailed planning, fewer workers on sites, better housekeeping, less overlap of trades in workspaces, clearer and better marked walkways, and one-way systems as well as the heightened awareness of occupational health and safety (ibid).

Hanan (2020) contends that focus on health and safety should not be a competitive gain. Therefore, putting rivalries aside and partnering with others who may be facing the same challenges could reinforce safety and keep workers safe. Strengthening safety methods should be regarded as a continuous process involving all parties with the same standard (ibid). Covid-19 has highlighted the benefits of clear messaging and consistency (Hanan, 2020; Damrose, 2020). Furthermore, Covid-19 has highlighted the importance for constant reminders, consistency, encouragement, and reinvigoration of safety and health messaging so that new behaviours are entrenched as habits (ibid). In addition, Covid-19 illustrated the benefits for new design changes over and above behavioural change to improve the wellbeing of workers.

METHODOLOGY

An extensive review of literature on the top was conducted from online databases, books, articles, and technical reports. A quantitative study was further employed, and data were analysed using IBM Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics



was adopted for the data analysis and further interpreted using inferential statistics. The total sample size for this study was 21 participants representing 21 construction companies in the Kwa-Zulu Natal province in South Africa. The construction companies were conveniently sampled based on proximity and familiarity with the researcher. Further justification of the method was because most construction sites were not open and/or were operating under restricted conditions during the lock down making it even more difficult to obtain results. This study is a pilot study forming part of an ongoing empirical research across South Africa in relation to the topic.

Profile of the Respondents

The median age of the respondents was 37 years ranging from a minimum of 26 years to a maximum of 69 years. The median years of experience were 11.5 years ranging from a minimum of 1 year to a maximum of 40 years. Most respondents were Health and Safety Managers/Officers (33.33%) followed by Civil Engineers and Artisans (23.80% each) and Construction Managers and Quantity Surveyors (9.52% each). The respondents level of education ranged from secondary/high-school to university education.

FINDINGS

The data range interpretations for the study were based on percentages, the 4-point Likert scales and 5-point Likert scales. The group interval coefficient value for the 4-point Likert scale was calculated as $(4) / 3 = 1.33$ and for the 5-point Likert scale was calculated as $(5) / 3 = 1.67$. The range interpretations for the 4-point Likert scale were used in Table 1 and for the 5-point Likert scale were used in Tables 5. For further ease of interpretation, the mean values for the 4-point Likert scale and 5-point Likert scale were interpreted as; high, medium and low.

Knowledge of Covid-19

Using a 4-point Likert scale the respondents were asked to rate their knowledge of Covid-19 where 1=no knowledge, 2=limited knowledge, 3=average knowledge and 4=excellent knowledge:

Table 24

Statement	Mean	Int.
Knowledge of Covid-19	3,62	H

It is apparent from the findings in Table 1 that most respondents had a very good knowledge of Covid-19. This is indicated by a mean value of 3.62 where 4.00 represented excellent knowledge.

Compliance with the general Covid-19 regulations at work

In Table 2, the respondents were asked to indicate whether the following procedures were followed in their workplaces:



Table 25

Statement	Percentage
I have been screened for COVID-19 at work	100%
I have been tested for COVID-19 at work	0%

It was evident from the responses that all sites conducted screening of employees upon entry on sites. However, respondents were not tested, and this may be attributed to the fact that it is not a prerequisite to test for Covid-19 unless one is presented with such symptoms.

Furthermore, the respondents were asked whether the facilities listed under Table-3 were available at work:

Table 26

Facility	Percentage
Own clinic	0%
Testing room	0%
Isolation room	42,86%

All sites did not have own clinics and testing rooms, however, 42.86% of the respondents reported that their sites had isolation rooms. It may be inferred that most contractors were less compliant in this regard. There is a need for further investigation.

As shown in Table 4, the respondents were asked to indicate whether in response to Covid-19, their organisations conducted health and safety risk assessment consistent with medical, scientific and government guidelines, and indicating the companies' duties to provide a safe working environment:

Table 27

Yes	100%
No	0%

All respondents agreed that health and safety risk assessments were conducted in response to the pandemic.

In Table-5 respondents were asked on a scale of 1 to 5 where 1=never, 2=seldom, 3=often and 5=always, to indicate how frequently the organizations practiced the following:



Table 28

Statements	Mean	Int.
The company provides Information and Support	4,42	H
We must adhere to social distancing in the workplace	4,71	H
The company conducts a continuous health monitoring system to ensure personal hygiene	4,48	H
The company provides strict training to ensure understanding of disease, prevention, control and compliance with the Covid-19 regulations	4,57	H
Our adherence to social distancing is continuously monitored	4,67	H
There are signs in the workplace reminding us to keep our distance from the next worker	4,71	H
The distance we are supposed to keep from other workers in the workplace or on site is marked with tape, stickers or paint	3,90	H
Company provides Masks	5,00	H
Company provides Gloves	4,00	H
Company provides Sanitizers	4,81	H
Company provides Showers	1,14	L
Company provides Laundry rooms	2,71	M
Company provides clean Running Water	4,67	H
Company provides Paper Towels	4,52	H
Company provides soap	4,76	H

The high level of agreement in Table 5 for most of the requirements indicated that most companies complied with the basic requirement for the safe execution of activities under the new regulations. Most companies adhered to social distancing which can be challenging in construction and also monitored if it was observed (mean = 4,71 and 4,67). There was strict training to ensure understanding of Covid-19 and also, companies provided information and support with regards to Covid-19 (mean = 4,57 and 4,42). All companies provided masks for the workers, most had sanitizers, soap and clean running water (mean = 5,00, 4,81, 4,76 and 4,67). However, most companies did not have showers, and few had laundry rooms (mean = 1,14 and 2,71).

Discussion and Conclusion

The findings in this study are consistent with the findings from previous literature. Unlike general health and safety regulations and requirements, there is an overall awareness of Covid-19 by everyone involved in the construction processes. These can be noted for the study as the level of



education ranged from Secondary High School to University and regardless of the workers' positions, there was awareness from both bottom line workers and managers. The realisation of Covid-19 by everyone is an important lesson for how health and safety should be administered in construction. Clear messaging with constant reminders to observe restrictions, timely response for adopting new measures and the heightened safety culture have proven effective for everyone to change their attitude and value human life. Previous studies on knowledge and compliance of health and safety regulations in South Africa pre-Covid-19 did not indicate any improvements as accidents happened at alarming rates. However, Covid-19 regulations and requirements received attention despite being less than a year old. Moreover, the construction industry put additional measures in place to ensure workers health and safety. An important message emerging from this study signifies that the construction industry ought to rethink health and safety compliance. It has been noted for a long time that the industry is slow to adopt change. However, this popular belief is now being confronted by the practical experience during the pandemic.

This study identified some of the lessons learned from the Covid-19 pandemic. The study reviewed literature on the topic and, primary data was further collected to investigate the lessons learned from the pandemic. The important findings to emerge from this study indicate that after all there is still hope that the construction industry can rethink health and safety, and this can be done almost immediately contrary to popular belief that the industry is resistant to change. There is hope for critical thinking of livelihoods and collaboration of industry stakeholders and international bodies that workers' lives can matter more than the construction processes. However, several limitations need to be acknowledged. This is a pilot study that forms part of an ongoing empirical study and was conducted under strict lockdown (level 4 and level 3) in South Africa. Therefore, the response rate was low with most contractors responding after a long time because of minimum capacity and tight working schedules. The scope of the study was limited to compliance with the general Covid-19 regulations/legislation in South Africa. Furthermore, although respondents were asked to rate their knowledge of COVID-19, it is worth noting that there are a wide-ranging biases and opinions associated with the perceptions around COVID-19. Future research could be conducted on knowledge, attitudes and perceptions related to COVID-19 in the construction industry and to validate these constructs.

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Perspectives on Mental Health among Asians in America under Impacts of the COVID-19

Hongyue Wu, Biao Kuang, Yunfeng Chen

Purdue University, USA

Correspondence: chen428@purdue.edu

Abstract: Mental health is a national public health concern, especially during the COVID-19 pandemic. However, little is known about the perspectives on mental health among Asians in America and its influencing factors relating to work and life. Therefore, this study aims to explore mental health and its influencing factors for Asians in America under the impact of the pandemic. A nationwide survey was conducted with Asians ($n=56$) and non-Asians ($n=108$) in America. Two-way Analysis of Variance (ANOVA) results showed that there were no significant differences in mental health, social support, and work-life balance between Asians and non-Asians, while significant differences were identified in work stress. Asians in American had a higher satisfaction level towards work stress. Also, simple linear regression carried out of the Asian samples revealed that younger individuals represented better mental health, lower work stress, more social support, and better work-life balance. Women also obtained more social support and achieved a better work-life balance than men. Last, the perspective on mental health and its influencing factors was shaped by simple linear regression, which showed that the satisfaction level of work stress, social support, and work-life balance all had positive relations with satisfaction level toward mental health. This study contributes to a deep understanding of mental health for Asians in America. The findings help in guiding policies, strategies, and supports to ensure mental health for Asians in America for current pandemic and future challenges.

Keywords: Mental health, COVID-19 pandemic, Asian, Work, Life.

1 INTRODUCTION

The widespread breakout of the COVID-19 pandemic and the resulting changes (e.g., social distance, stay-at-home orders, work from home, etc.) have caused serious effects on people's daily and working activities (Guo & Chen, 2020; Kumar & Nayar, 2020; H. Wu & Chen, 2020), which has led to mental health issues, such as anxiety and depression (Adams-Prassl et al., 2020; World Health Organization, 2020). People's mental health issues have great impacts on individuals, families, and the whole society during and after the outbreak (Cullen et al., 2020). Also, the consequences of poor mental health are long-lasting and have broad impacts on individuals' work and life (Fitzpatrick et al., 2020; Pfefferbaum & North, 2020). Therefore, mental health, as a national public health concern during the COVID-19 pandemic, should be investigated more. Increasing evidence suggested that some particular populations, e.g., minority groups such as Asians in American, may be more vulnerable due to the risks from the pandemic, which influences mental health (Rajkumar, 2020; Taggart et al., 2021). However, little is known about Asians' experiences of mental health relating to the changes in work and life, which needs further exploration.



Therefore, this study aims to investigate the mental health of Asians in America as well as exploring its potential factors relating to work and life under the impacts of the pandemic. First, an online survey was distributed to collect data before and during the pandemic. Second, the two-way Analysis of Variance (ANOVA) was applied to explore the differences before and during the pandemic as well as across ethnic groups. Then, simple linear regression was used to further investigate the impact of COVID-19, gender, age, and marital status on mental health within Asians. Finally, simple linear regression models were developed to examine the relations between mental health and its three potential influencing factors before and during COVID-19, respectively.

2 LITERATURE REVIEW

During the COVID-19, anxiety and depression are common mental health issues (Rajkumar, 2020), which are influenced by personal characteristics and changes in work and life (Fitzpatrick et al., 2020; Giorgi et al., 2020). Work- and life-related factors affect people's ability to cope with challenges originating from the pandemic, and further contribute to exacerbating or moderating the effect of the pandemic on people's mental health (Giorgi et al., 2020). Specifically, work stress is a major factor impacting the mental health of individuals (Love et al., 2010). During the pandemic, work stress is still a major resource causing a higher risk of depression and anxiety (Sun et al., 2020). Also, work-life balance is a critical factor. People were forced to work from home due to the stay-at-home orders (Meyer et al., 2020), which is beneficial for work-life balance and further facilitates moderating mental health issues (Haar et al., 2014). However, some studies also indicated that COVID-19 caused work-life conflict, which leads to worse mental health for individuals (Schieman et al., 2021). In addition, social supports play a critical role in moderating mental health. Peoples have more time with their family members and get more supports from family and friends (Zhang & Ma, 2020), which alleviates mental health issues.

For individual characteristics, such as gender, age, marital status, ethnicity, etc., Gualano et al., (2020) found being married reduced the probability of mental health issues impacted by quarantine. Also, females, Asians, and families with children are vulnerable respondents who have higher possibilities of getting mental health issues in the U.S. (Fitzpatrick et al., 2020). But this study did not provide further explanation and explore potential factors. Moreover, in terms of Asians in America during the pandemic, the changed work and living environment influence their mental health as well (Giorgi et al., 2020). However, the perspectives and experiences of Asians' mental health relating to work and life in the U.S. are still unclear.

Overall, during the COVID-19, people's work and life changed broadly, which impacts individuals' mental health. Although some studies analyzed the mental health of Asians in America during the pandemic, there is still a lack of study on their mental health relating to work and life. This paper analyzes the mental health of Asians in America under the impact of the pandemic considering individual factors above and further explores its influencing factors considering work and life.

3 RESEARCH METHODOLOGY

3.1 Participants

A nationwide survey was distributed to employees in the U.S. Individual emails were the major resources inviting participants relying on the personal contacts from LinkedIn and email lists collected by the researchers. Also, the survey link was posted on social media, such as



LinkedIn and Facebook. In addition, diverse professional associations and universities were contacted to help distribute the survey. After removing the person-level missing data (Newman, 2014), some participants outside the U.S., and four responses without ethnic information, there were 164 participants. Each participant provided two sets of responses (i.e., before the pandemic and during the pandemic) for all the variables. The single imputation method was used to impute the item-level missing data by replacing N/A using mean values (Newman, 2014). Therefore, 328 set responses were used for further analysis.

Among the 164 participants, White accounted for 57.14% ($N=96$), Asian accounted for 33.33% ($N=56$), while 7.14% of the participants had other ethnicities ($N=12$). Then, 23.21% of the participants were women, while men accounted for 73.81%. One participant preferred not to disclose the gender. For marital status, 66.67% of the participants were married or lived together, while single or divorced participants accounted for 29.17%. Finally, for the ages, the percentages of participants belonged to the age groups of 20-29, 30-39, 40-49, 50-59, and older than 60 years were 20.73%, 31.10%, 18.90%, 16.46%, and 12.80%. For the 56 Asians in American, the majority of them worked in management, professional and related occupations, including professors in the education area, project management occupations, etc., which is following current statistics (U.S. Bureau of Labor Statistics, 2021). Also, over 70% of employed Asians in American were between 25 – 54 years old in the sample, which is also supported by the national statistics (U.S. Bureau of Labor Statistics, 2021).

3.2 Measures

COVID-19 pandemic. The COVID-19 pandemic was a dummy-coded variable in this study. 0 meant before the pandemic, while 1 indicated during the pandemic.

Demographic information. Four variables were used to measure demographic information in the study. First, ethnicity was the most critical independent variable in this study. It was defined as a dummy variable, where 1 indicated Asian and 0 indicated non-Asian. Then, gender is a dummy variable, where 1 indicated man and 0 meant woman. Next, age was measured by providing the exact numbers. Finally, marital status was also a dummy variable that 1 indicated married or lived together, while 0 showed single or divorced.

Mental health. A single item was used to measure the overall mental health. The question in the survey was “Please rate your satisfaction level of the mental health (e.g., depression/anxiety/etc.) along a five-point Likert scale.” 1 indicated “very dissatisfied”, while 5 was “very satisfied.”

Influencing factors of mental health. Three possible influencing factors of mental health during the pandemic were used in the study: work stress (Love et al., 2010), social support (Zhang & Ma, 2020), and work-life balance (Haar et al., 2014). They were also measured by the satisfaction level of a single item using “Please rate your satisfaction level of the following items along a five-point Likert scale.” Similarly, 1 was “very dissatisfied”, while 5 showed “very satisfied.”

3.3 Analysis

First, descriptive analysis was applied to show the mean values and standard deviations (S.D.) of variables across groups. Then, for all participants, the two-way ANOVA method using F -test relying on PROC GLM package in SAS software was used to identify whether COVID-19 and ethnicity had significant impacts on mental health and its influencing factors (i.e., work stress, social support, and work-life balance). Because the groups in two-way ANOVA have unequal

sample sizes, Type III sums of squares were appropriate to report when the assumption is that the treatment means have equal importance and no empty cells (Kutner et al., 2005). It was supported that the unequal treatment sample sizes often do not affect the importance of treatment means (Kutner et al., 2005); and the sample in the study did not have empty cells after imputing missing values. Thus, two-way ANOVA is a proper method here. Next, simple linear regression based on *t*-test using PROC REG package in SAS software was performed to examine the effects of COVID-19 and demographic indicators (i.e., gender, age, and marital status) on mental health within the Asian group separately. Finally, simple linear regression was applied to identify the relations between each of three influencing factors and mental health for Asians in America, respectively. In addition, a power analysis was used to test the sample size for each method using G*power software (Erdfelder et al., 2009; Faul et al., 2007).

4 RESULTS

4.1 Descriptive analysis

Table 1 shows the mean values and S.D. of mental health and its three influencing factors under different groups. Participants had a higher satisfaction level of work stress, social support, and work-life balance during the pandemic, while satisfaction towards mental health was decreased during COVID-19. Then, Asians in America had a lower satisfaction level for mental health and social support than other ethnic groups, while Asians were more satisfied with work stress and work-life balance. Table 2 showed the mean values and S.D. for the 56 Asians in America. During COVID-19, they were less satisfied with mental health, but more satisfied with the other three factors. Women had a higher satisfaction level than men for all the variables. As for age, participants who were younger than 34 years old (average age of the Asian group) were more satisfied with all the variables than senior participants. Finally, married participants had a higher satisfaction level for mental health, while they experienced less satisfaction for work stress, social support, and work-life balance.

Table 1: Descriptive analysis of variables before and during pandemic for all participants

Items		Mental health	Work stress	Social support	Work-life balance
Before COVID-19	Mean	4.03	3.62	4.05	3.73
	S.D.	0.88	1.08	0.82	1.02
During COVID-19	Mean	3.98	3.78	4.12	3.91
	S.D.	1.05	1.09	0.98	1.13
Asian	Mean	3.96	3.98	3.99	3.85
	S.D.	0.93	0.96	0.93	1.07
Non-Asian	Mean	4.03	3.56	4.13	3.80
	S.D.	0.98	1.13	0.88	1.09

Table 2: Descriptive analysis of variables within Asian group

Items		Mental health	Work stress	Social support	Work-life balance
Before COVID-19	Mean	4.07	3.94	3.89	3.83
	S.D.	0.83	0.92	0.89	1.02
During COVID-19	Mean	3.86	4.01	4.09	3.87
	S.D.	1.02	1.00	0.98	1.13
Men	Mean	3.94	3.96	3.92	3.77



	S.D.	0.95	0.97	0.94	1.10
Women	Mean	4.13	4.06	4.44	4.38
	S.D.	0.81	0.93	0.81	0.72
< 34 years old	Mean	4.03	4.08	4.13	3.98
	S.D.	0.96	0.96	0.88	1.14
>= 34 years old	Mean	3.86	3.82	3.77	3.66
	S.D.	0.88	0.95	0.99	0.94
Married	Mean	3.95	3.90	3.90	3.77
	S.D.	0.91	0.92	0.97	1.05
Not married	Mean	3.92	4.03	4.07	3.89
	S.D.	0.96	1.01	0.88	1.12

4.2 Two-way Analysis of Variance (ANOVA) for Asians and Non-Asians

Table 3 illustrates the impacts of COVID-19 and ethnicity on mental health, work stress, social support, and work-life balance. The power of both main effects and two-factor interactions was 0.89, which is higher than the commonly accepted value of 0.8 (Cohen, 1988; Kutner et al., 2005; MacCallum et al., 1996). It was indicated that the pandemic did not have a significant impact on all four variables. Also, Asian and non-Asian groups did not show significantly different mental health. And no significant relations were found for both social support and work-life balance between Asians and non-Asians. However, work stress was significantly impacted by ethnicity ($p < 0.01$). According to means values in Table 1, Asians had a significantly higher satisfaction level on work stress than non-Asians in America.

Table 3: Two-way ANOVA results considering COVID-19 and ethnicity

Dependent Variable	Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Mental health	COVID-19	1	0.60	0.60	0.65	0.42
	Ethnicity	2	0.30	0.30	0.33	0.57
	COVID-19*ethnicity	2	1.15	1.15	1.23	0.27
	Error	322	302.33	0.93		
	Total	327	304.00			
Work stress	COVID-19	1	1.42	1.42	1.24	0.27
	Ethnicity	1	12.89	12.89	11.20	< 0.01
	COVID-19*ethnicity	1	0.31	0.31	0.27	0.61
	Error	324	372.83	1.15		
	Total	327	388.11			
Social support	COVID-19	1	0.72	0.72	0.89	0.35
	Ethnicity	1	1.47	1.47	1.80	0.18
	COVID-19*ethnicity	1	0.72	0.72	0.88	0.35
	Error	324	264.13	0.82		
	Total	327	266.69			
Work-life balance	COVID-19	1	1.58	1.58	1.36	0.25
	Ethnicity	1	0.17	0.17	0.15	0.70
	COVID-19*ethnicity	1	0.88	0.88	0.75	0.39
	Error	324	378.41	1.17		
	Total	327	382.15			

4.3 Simple Linear Regression within Asians in American

Within the Asian group, the impacts of COVID-19, gender, age, and marital status were examined. The power of simple linear regression analysis using the sample was 0.89, which is higher than the commonly accepted value of 0.8 (Cohen, 1988; Kutner et al., 2005; MacCallum et al., 1996). All the statistically significant results are shown in Table 4. Gender factor had a significant impact on social support ($b = -0.52, p = 0.04$) and work-life balance ($b = -0.61, p = 0.03$). Women were more satisfied with social support and work-life balance. Then, age was the most important factor that contributed to significant differences in mental health ($b = -0.02, p = 0.02$), work stress ($b = -0.03, p < 0.01$), social support ($b = -0.03, p < 0.01$), and work-life balance ($b = -0.03, p < 0.01$). Younger participants had higher satisfaction levels toward mental health, work stress, social support, and work-life balance. However, COVID-19 and marital status were not significant factors for Asians.

Table 4: Simple linear regressions of COVID-19 and demographic indicators for Asians in America

Dependent Variable	Independent Variable	DF	Parameter Estimate	S.D.	t Value	Pr > t
Social support	Gender	1	-0.52	0.25	-2.09	0.04
Work-life balance	Gender	1	-0.61	0.29	-2.14	0.03
Mental health	Age	1	-0.02	0.01	-2.41	0.02
Work stress	Age	1	-0.03	0.01	-2.96	<0.01
Social support	Age	1	-0.03	0.01	-3.90	<0.01
Work-life balance	Age	1	-0.03	0.01	-3.08	<0.01

Finally, Table 5 indicates the simple linear regression models between mental health and its potential three influencing factors in the Asian group, respectively. The power was also 0.89. All three factors had positive relations with mental health both before and during COVID-19. Work stress was the most important factor because it had the largest parameters in both situations ($b = 0.77, p < 0.01$ and $b = 0.69, p < 0.01$). Work-life balance was the least important factor among the three because it had the smallest parameters ($b = 0.52, p < 0.01$ and $b = 0.47, p < 0.01$). The differences between parameters considering COVID-19 situations were smaller than 0.05. However, R-squares for the regressions before COVID-19 were larger than during COVID-19. The percentages that the factors can explain the changes in mental health were higher before COVID-19 than during COVID-19. In addition, R-square also supported that work stress was the most important factor that can explain more changes in mental health.

Table 5: Simple linear regressions of influencing factors and mental health for Asians in America

COVID-19	Independent Variable	DF	Parameter Estimate	S.D.	t Value	Pr > t	R-square
Before COVID-19	Work stress	1	0.77	0.06	12.45	<.01	0.74
	Social support	1	0.54	0.10	5.22	<.01	0.34
	Work-life balance	1	0.52	0.08	6.07	<.01	0.41
During COVID-19	Work stress	1	0.69	0.10	6.84	<.01	0.46
	Social support	1	0.58	0.12	5.00	<.01	0.32
	Work-life balance	1	0.47	0.10	4.48	<.01	0.27



5 DISCUSSIONS

Although descriptive analysis showed differences between demographic groups and before and during pandemic for mental health, work stress, social support, and work-life balance, the specific statistical analyses reported more significant relations.

First, Asians and non-Asians had no significant differences in satisfaction levels toward mental health, work-life balance, and social support. Thus, Asian is not more vulnerable considering mental health, work, and life, even under the impact of the pandemic. Then, Asians had a significantly higher satisfaction level on work stress than non-Asians in America, which is not following the results of current research that Asians in America experienced more stress and pressure in the workplace during the pandemic (Kantamneni, 2020). One possible reason is the different occupations that Asians and non-Asians mainly belong to. It was reported that 57% of Asians work in management, professional, and related occupations, which is the largest portion of all employees in the U.S. (U.S. Bureau of Labor Statistics, 2021). They are not the occupations that experienced high work stress (Johnson et al., 2005). Also, the larger sample size of non-Asians than Asians in this study may be another reason. More participants should be reached out in the future to further examine the differences.

Second, within the Asian groups, simple linear regression indicated that age showed significant impacts on mental health, work stress, social support, and work-life balance. Younger Asians in American reported a slightly higher satisfaction level toward the four variables. The main reason is that senior adults are more vulnerable groups during the pandemic (Li et al., 2021). The more potential risks of COVID-19 may impact their work, life, and mental health. However, the finding is conflicting with existing studies identifying that older participants reported better mental health status, more social support, and better work performance (Bruine de Bruin, 2021; Nwachukwu I et al., 2020; Pieh et al., 2020). The most critical reason is that the existing work focused on general populations in different areas, e.g., the US, Australia, Canada, etc., instead of Asians in American. Thus, the finding of this study showed the unique impacts of age within Asians in American groups. More work should be done to further explore the relations. Next, gender showed significant impacts on social support and work-life balance for Asians. Women had a higher satisfaction level toward social support and work-life balance than men. Females have better social support resources because of the different sex roles for social interaction (Vaux, 1985). Feminine role is described as warmth, compassion, and supportiveness, which can both provide and receive more supports (Vaux, 1985). Then, the result of work-life balance is different from the current study for all the populations (Starmer et al., 2019). One possible explanation is that women experienced more advantages for work-life balance during working from home (Walker et al., 2008). Also, employed Asian women had the highest percentage of working in management, professional, and related occupations than other women (U.S. Bureau of Labor Statistics, 2019), which may allow them to balance work and life better.

Finally, higher satisfaction levels of work stress, social support, and work-life balance can contribute to a higher satisfaction level of mental health for Asians in American, which can be supported by previous studies (Hämmig & Bauer, 2009; Oakman et al., 2020; Sun et al., 2020). In particular, work stress was the most important factor among the three both before and during COVID-19. Thus, reducing work stress is a possible effective strategy to enhance mental health for Asians in American. Finally, the percentages that the three factors can explain mental health



were reduced during the pandemic. One possible reason is that the pandemic brings about a lot of stressors and risks that cause mental health issues besides the three factors in the study (Xiong et al., 2020), especially the health concerns (Fitzpatrick et al., 2020), stay-at-home orders (Adams-Prassl et al., 2020), etc., which reduced the percentage that mental health can be explained by the selected factors. More indicators should be included during the pandemic to estimate people's mental health.

6 CONCLUSION

Mental health is a critical public health concern in the U.S., especially under the impacts of the COVID-19 pandemic and for minorities (e.g., Asians in America). The study aims to explore mental health and its influencing factors for Asians in America under the impact of the pandemic. The satisfaction levels of mental health and its influencing factors (i.e., work stress, social support, and work-life balance) were collected before and during the pandemic. The results indicated that mental health, work-life balance, and social support did not show significant differences between Asians and non-Asians, while Asians had a higher satisfaction level toward work stress. Within the Asian group, age and gender are significant factors. Younger Asians in America represented better mental health, lower work stress, more social support, and better work-life balance. Also, women obtained more social support and achieved a better work-life balance than men. Last, the higher satisfaction level of work stress, social support, and work-life balance contributed to more satisfaction toward mental health. This study contributes to a deep understanding of mental health for Asians in America. The findings can help in guiding policies, strategies, and supports to improve mental health for Asians in America for current pandemic and future challenges.

However, this study has some limitations. First, the sample size was limited. Although 56 Asians and 108 non-Asians satisfied the requirements of the ANOVA test and simple linear regression, more participants should be included to further test the relations. Then, the single items were used to measure variables. The comprehensive matrix or questionnaires can be applied in the future to improve reliability. Finally, only three influencing factors were considered in the study, while many other factors impact the mental health of individuals, which should be included in future work.

CONFLICT OF INTEREST DISCLOSURE

No conflicts of interest were identified for all authors.

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EXPLORING ACCULTURATION STRESSORS OF ETHNIC MINORITY WORKERS IN THE CONSTRUCTION INDUSTRY

Khursheed Ahmed, Mei-Yung Leung

City University of Hong Kong, Hong Kong

Correspondence: akahmed2-c@my.cityu.edu.hk

ABSTRACT

Due to the shortage of labor, the number of ethnic minority workforce is increasing in the construction industry of Hong Kong. However, ethnic minority construction workers (EM-CWs) may expose to various stressors and experience a high level of stress when working in a foreign country. Although it is well known that excessive stress severely influences individual performance, the ethnic minority problems in the construction sector has not been studied substantially. This study, thus, aims at identifying the stressors and stress of EM-CWs in the industry. Three standardized focus groups were conducted with EM-CWs from Nepal, Pakistan, and India in Hong Kong. Using a contextual analysis of focus group discussions, the findings explored four acculturation stressor items including *strange feeling*, *adjustment*, *new environment*, and *difficulty to find a job*, three stress symptoms (i.e., *anger*, *tension*, and *fear*), and three types of *task performance* (i.e., *working speed*, *making mistakes* and *losing focus*) for EM-CWs in the industry. This study is a preliminary effort toward the first step in developing a stress management model for EM-CWs. It is envisaged that the findings will help to devise an integrated Stress-Performance model for EM-CWs in Hong Kong. Based on the findings of this study, companies hiring EM-CWs have to take special care of them, e.g., offering trade skills training, language courses, and mentorship schemes. Moreover, assistance to assimilate in the new culture and work setting to reduce unemployment of EM-CWs are suggested.

Keywords: Construction workers, Ethnic minority, Performance, Stressors, Stress.

INTRODUCTION

Construction industry has been recognized as the most labor-intensive and stressful industry (Leung et al., 2017; Loosemore et al., 2003). Due to shortage of labor, the employment of immigrant workers has been globally increased, particularly in the construction industry (Haque and Ismail, 2002). In fact, a number of construction workers are ethnic minorities in the USA, the UK, and Singapore (Al-bayati et al., 2018; Dutta et al., 2018; Meardi et al., 2012). The inflow of the ethnic minority workforce in Hong Kong has also been risen considerably from 7.4% to 11.9% in 2011 to 2016 respectively (Census and Statistics Department, 2011, 2016), mainly from South Asian (SA) countries, such as Nepal, Pakistan, and India. According to Census Statistics Department of Hong Kong, ethnic minorities (EMs) refer to persons who reported themselves being of non-Chinese ethnicity in the Population Census (Census Statistics Department, 2016). The status of these groups is not associated with immigration, because many SA families residing in Hong Kong for decades and can be considered as a Hong Kong "residents". In policymaking and census statistics, the phrase "ethnic minority" is frequently used to classify non-Chinese people in Hong Kong (O'Connor, 2018). The current study sticks to the official term of EM in Hong Kong representing the EM-CWs. Usually,



migrants are referred to the most recent category of ethnic minorities those do not hold the nationality of the host country. However, later these immigrants can be considered as an ethnic minority when they received citizenship of the host country. In both social and political contexts, minority groups are regarded differently from the majority (Maoláin et al., 2016). Their language, values, background, beliefs, and way of life are frequently different from the majority.

Based on Berry's acculturation concept, EM groups experience changes in certain aspects of their systems while living in the other dominant culture (Berry, 2006; Tonsing, 2013). During the acculturation process, they may often face unpleasant experiences that cause stress to them. Past studies mentioned that minority workers have been more prone to a high degree of risks, and health hazards compared to their local counterparts (Galvan et al., 2015; Oswald et al., 2018). Thus, it can be inferred that doing job in a foreign country may cause stress to ethnic minorities, due to the differences between their hometown and the host country (Chen et al., 2009). In acculturation process, social and cultural related issues, including settlement, adjustment, communication, and employment in a new society, may be the key sources of stress for foreign workers (Kim et al., 2015).

Both clinical and empirical studies have proved that reasonable stress may stimulate the expected outputs, while excessive stress may be detrimental to individual's performance and health (Abbe et al., 2014; Leung et al., 2015). Statistics show that stress-associated losses in Hong Kong exceeds HK\$230 million per year (Tsui, 2019), while it costs around £70 to £80 billion annually in the UK (OECD, 2018). Although stressors and stress of native CWs are well documented (Leung et al., 2012, 2015; Liang et al., 2018), the situations for EM-CWs may be more complicated in the industry. Therefore, the study strives to improve the performance of EM-CWs in Hong Kong by identifying their stressors and stress in the industry.

Stressors

In acculturation process, EM-CWs may experience numerous problems and difficulties in the new place, such as cultural differences between their own culture and the foreign culture (Tonsing et al., 2016), different perceptions towards work from their home country, financial difficulties, homesickness, sense of loss, lack of support, etc., which may become a source of stress (i.e., stressors) (Leung et al, 2015; Peiro et al., 2020). Therefore, they may feel stress, especially facing new workstyle within limited time. Furthermore, living in unfamiliar traditions involves many changes in terms of languages, cultural events, beliefs, and so on. Different norms and values may induce stress to EM-CWs in daily work (Hovey, 2000; Leung and Chan, 2012). Several local studies on ethnic minority have mentioned difficulties and barriers they combat in different occasions including jobs, houses, and education in the host country (Crabtree and Wong, 2012; Frost, 2004; Ku, 2006), but difficulties encountered by EM-CWs, particularly in the construction industry is yet to be explored.

Stress

Stress is an emotional activity generating from the perception of the exterior setting (Lazarus 1995). It refers to a negative emotional state. In organizational context, it may cause significant losses to organizations in terms of compensation costs, health problems, reduced productivity, increased mistakes, and absenteeism (Finney et al., 2013). Generally, most ethnic minority populations have poorer psychological health condition in compare to the local population (Vandan et al., 2019). It is expected that EM-CWs may also be experiencing the highest emotional stress while residing in a host country,



particularly working in the construction industry. Past studies have also documented that EM-CWs are suffering from emotional stress due to communication problems, discrimination, prejudice and negative stereotyping, and so on (Brown et al., 2011; Tongsing, 2013; Wong and Lin, 2014). In addition, emotional stress has been associated with task performance of construction workers (Leung et al., 2005).

Task performance

The task performance is usually associated with the work productivity (Leung et al., 2017). Construction workers suffered from stress may lead to poor performance in both quality and speed of task accomplishment because stress makes them too tense, worry, and disturb (Liang et al., 2018). In fact, excessive stress brings inflexibility in behavior, seriously effecting on difficult tasks, where attentions are needed (Leung et al., 2005). Moreover, construction jobs involve various complexities and interruptions, which required high concentration and precision to handle those tasks. Under stress, individual's mind could be fully occupied, slowing down efficiency, and hindering overall task performance (Ganster and Rosen, 2013). Thus, it could be hypothesized that the task performance of EM-CWs may be affected by stress, and various stressors in the industry. Therefore, it is crucial to identify the performance indicator of EM-CWs to improve their task performance and to prevent significant loss to the project.

RESEARCH METHOD

Focus Groups

Focus groups is a qualitative research method, through which small groups of people gather to discuss particular subjects. The interactive method in focus groups allows participants to share important information, perceptions, and viewpoints in detail. It can also be utilized to explain and match substantial results of the quantitative data (Creswell and Clark, 2017). This method has extensive application, and increasingly adopted in the studies of health and safety (Nili et al., 2017).

Focus groups were designed to explore the acculturation stressors, stress, and performance of EM-CWs, three focus groups (i.e., Nepal, Pakistan, and India). These three groups were consisted of participants having relatively homogenous backgrounds. The sample size of focus groups varied for different researches, while most of the researchers agreed on a group of 6-12 participants (Krueger and Casey, 2014). This study decided to have a group of 6-10 participants for each focus group, therefore more than 10 participants were invited for each focus group. However, 5-8 members (i.e., 6 in the Nepali group, 8 in Pakistani group, and 5 in the Indian group) appeared for the group meetings. Participants in the three focus groups were working in the construction industry of Hong Kong for more than one year. The researcher had prepared, and used a standardized set of semi-structured open-ended questions based on the literature during the group discussion. To get a systematic qualitative data collection and analysis, the discussions for all groups were arranged in the identical structured framework. The group discussions lasted for 2-3 hours up to the saturation of information. At the end of discussions, feedbacks were obtained from the focus group participants on the collected data.

Contextual analysis was used to analyze the collected data from the three focus groups (Liang et al., 2018). Data were collected via several approaches, such as: i) audiotapes; ii) worksheets from each participant; and iii) immediate notetaking during the discussions were adopted. Each response from the members under the context was carefully inspected by researchers. The data were merged with the unit of analysis



based on the themes and further categorized into different groups according to previous literature. It was combined into inclusive tables to represent the views of the entire group instead of individuals' opinions (Stewart and Shamdasani, 2014).

RESULTS

Based on the data collected from the focus groups, stressors, stress, and performance of EM-CWs were classified in Table 1. The findings have revealed four types of acculturation stressors, including strange feelings, adjustment, difficulty to find a job, and a new environment. For example, a focus group participant said that “*we adjust various problems in Hong Kong, such as foods, dresses, and languages*” (NGW). It shows that when EM-CWs contact different cultural systems in the host country, they can feel unknown to the dominant culture and face various difficulties to settle in. Moreover, due to a lack of information about the job market in the new society, they can also experience many issues to seek jobs. In fact, it can increase their stress when they fail to get the job for which they leave their hometown.

Table 1 Summary of EM-CWs' Acculturation Stressors, Stress, and Performance

Items	Manifestation	Group			Descriptions
		NGW	PGW	IGW	
Acculturation stressors	Strange feeling	X	—	—	NGW: They feel very strange when they migrated to Hong Kong.
	Adjustment	X	—	—	NGW: We adjust various problems in Hong Kong, such as foods, dresses, and languages.
	Difficulty to find job	—	X	—	PGW: It is very difficult to find a job and, thus I worried about my migration.
	New environment	X	—	—	NGW: The method of construction is totally different and complex in comparing to my hometown, which often leads to stress.
		—	—	X	IGW: It is challenging to work in a new environment of Hong Kong.
Stress	Tension	X	—	—	NGW: There is a lot of stress and tension in Hong Kong.
	Anger	X	—	—	NGW: Our inability to attend cultural festivals causes anger and frustration.
	Fear	—	X	—	PGW: New workers often fear about mistakes at their work.
	Stress	—	X	X	IGW: They feel stress when run into financial crisis because it is impossible to spend a single day without money in Hong Kong.
Task performance	Losing focus	X	—	—	NGW: We cannot concentrate on the work under stress.
		—	—	X	IGW: Pressure has a strong effect on our job , particularly disturbing the focus from our current tasks.
	Working speed	X	—	—	NGW: When we are emotionally tired, our working speed are affected negatively .
		X	—	—	NGW: In stressful situations, the given task from foreman cannot be performed with normal speed by losing focus .
		—	X	—	PGW: EM's working speed is much higher than the Chinese.
	Making mistakes	—	X	—	PGW: When we work under stress, the chances of our mistakes are increased .

Note: NGW = Nepali general CWs; PGW = Pakistani general CWs; IGW = Indian general CWs; and X = excerpt.



Furthermore, EM-CWs have identified four kinds of symptoms such as tension, anger, fear, and stress. EM-CWs mentioned that “there is a lot of stress and tension in Hong Kong” (NGW). It is reasonable that EM-CWs can feel fear, tension, and stress, while entering the advance and demanding working environment, which is quite different from their previous working experiences. As a result of acculturation stressors and subsequently stress, task performance of EM-CWs is affected in various aspects, including losing focus, working speed, and making mistakes. Focus group participants expressed that “*when we work under stress, the chances of our mistakes are increased*” (PGW). In addition, they admitted that “EM’s working speed is much higher than the Chinese” (PGW).

DISCUSSIONS

Participants from the ethnic minority groups revealed acculturation stressors (i.e., strange feelings, adjustment, new environment, and difficulty to find a job) for EM-CWs in the industry, while they often expressed three symptoms of stress (i.e., anger, tension, and fear) and the three types of performance (i.e. working speed, making mistakes and losing focus) in the daily job tasks (see Table 1).

Acculturation Stressors

EM-CWs revealed that acculturation was a critical source of stress to them. When an individual migrates to a foreign country, he/she faced many difficulties to settle in the host country, such as *strange feelings, adjustment challenges, new environment, difficulty to find a job*, and so on. The Nepali group identified that “*they feel very strange when they migrated to Hong Kong*” (NGW). In fact, the lifestyles of ethnic minorities, such as food, dresses, languages, etc., were sharply different from the majority population in Hong Kong, i.e., Chinese dominant (Tonsing, 2013), which created barriers for them to *adjust* their lifestyle in the host society. For instance, NGW group experienced various problems *to adjust in Hong Kong* (NGW). Additionally, ethnic minorities had a very limited social network and social capital that could help in securing employment opportunities. Hence, Pakistan general CWs stated, “*it is very difficult to find a job and, thus, I worried about my migration*” (PGW). Thus, EM-CWs experienced various challenges to adjust in the new society.

On the other side, the different working environments and systems between their hometown and host country were also identified as a big challenge for EM-CWs. The Indian group highlighted that “*it is challenging to work in a new environment of Hong Kong*” (IGW), while Nepali group also stated that “*the method of construction is totally different and complex in comparing with my hometown*, which often leads to *stress*” (NGW). In fact, individuals in an unfamiliar environment with insufficient information about that culture and norms will be stressed (Leung and Chan, 2012). The construction projects in Hong Kong are complex, dynamic and advance, involving various technologies, safety rules, sustainability, etc. Therefore, EM-CWs easily experienced stress when they faced new working environment with limited of time to understand the tasks.

Stress

The present study explored that EM-CWs experience various emotional stress symptoms, which mainly manifest as anger, worry, and fear. When an individual arrives at a new environment with different culture, the experience for setting up a social network can create a high level of emotional stress. The uncertainty about his settlement in a strange environment can be fearful (Berry, 2006). The PGW group



stated: “new workers often *fear about mistakes at their work*”. In addition, far away from home, minority workers cannot enjoy their cultural and religious activities in the host country, which can also be source of stress. For instance, Nepali group expressed that “our inability to attend cultural festivals *causes anger and frustration*” (NGW4). Furthermore, the life in Hong Kong is tough, and fast-pace, which can be challenging for EM-CWs (Leung, 2018). Therefore, the NGW group mentioned the presence of *stress and tension in Hong Kong*. Similarly, another group (IGW) expressed that “they *feel stress when run into financial crisis*, because it is impossible to spend a single day without money in Hong Kong”.

Task Performance

The study revealed that task performance of EM-CWs reduced under stress. The EM-CWs identified their task performance in three aspects, including *working speed*, *making mistakes*, and *losing focus* (see Table 1). One of the groups (NGW) mentioned that “in stressful situations, the tasks given from foreman *cannot be performed with normal speed* by losing focus”. In fact, the EM-CWs were emotionally exhausted under stress and definitely impaired their job performance, e.g., *work slow* during emotionally tired (NGW). Furthermore, the experience of stress not only diminished EM-CWs’ working speed, but also increased the mistakes. For instance, “*when we work under stress, the chances of our are mistakes increase*” (PGW). Interestingly, focus group members highlighted that task performance was closely related to their concentration, such as “*we cannot concentrate on the work under stress* (NGW). Therefore, stable and calm mindset played an essential role at the job, such as “pressure has a strong effect on *our jobs*, particularly *disturbing the focus from our current tasks*” (IGW). On the other hand, EM-CWs admitted that their task performance was recognized by employers. Particularly, in heavy physical tasks, they performed better than the local counterparts.

RECOMMENDATIONS

Practical Recommendations

The current study explored acculturation stressors, stress symptoms, and task performance of EM-CWs in Hong Kong. To improve the performance of EM-CWs, construction companies are suggested to reduce their acculturation stressors (i.e., strange feeling and adjustment) by *promoting social cohesion* (i.e., *engaging EM-CWs and local workers in positive interactions*) and *offering career development support* such as *trade skills development training*, *language courses*, *mentorship scheme* to EM-CWs. Social cohesion programs can remove EM-CWs’ strange feeling and ease to adjust in the new environment. It can enable them to interact as well as to know the norms and cultural values of host society. On the other hand, through career support, EM-CWs can develop various work trades skills, which can open a wide range of job opportunities in the market. In fact, employment can support them to adjust the life changes both socially and financially. Additionally, they can meet different national and skill levels of people at the job, increases the chance for developing new friends, cultural learning, and other skills.

Furthermore, learning Chinese language can also enhance adaptability in Hong Kong. It could assist them in seeking job opportunities. In fact, fluency in Chinese language is prerequisite in most of the jobs. It is, thus suggested to *offer language trainings* to EM-CWs to minimize the problems in finding employment (HK Unison 2017; Jahoda et al., 2017). Finally, it is important to develop relationships and social networks in the construction industry in order to secure the work. Mentorship schemes and programs can enable EM-CWs to develop relations and networks, and consequently empower them to get the jobs in the



future. Hence, the findings of this study will serve employers to manage EM-CWs' related stress, preventing the downward spiral of reduced performance.

Further Research

The cultural differences among the EM-CWs may have long-term consequences for the construction industry, such as discrimination, racism, language barrier, etc. To optimize stress management, both quantitative and qualitative research methods are suggested to explore other variables related to EM-CWs in the future studies. This study is a preliminary effort to act as the first step in developing a stress management model for EM-CWs. In order to develop a comprehensive stress management model for EM-CWs, large number of focus groups including skilled workers, foremen, engineers, etc., are required in future studies. Additionally, to validate the qualitative research method, quantitative research methods such as questionnaire surveys are needed to investigate the statistical or empirical relationships among the stressors, stress, and performance of EM-CWs.

In addition, the current study mainly focused on exploring the acculturation stressors and their associated repercussions on the stress and task performance of EM-CWs. In fact, these findings can be precursors to future studies, particularly to develop an effective stress-performance model for EM-CWs. In order to establish a holistic stress-performance model, future studies should include different types of stress (e.g., emotional, physical, and job stress) and performance (e.g., task, interpersonal, organizational, and safety performance) for EM-CWs.

Furthermore, to understand the influence of acculturation on EMs based on their time spent in the host country, it is recommended to compare different groups of EM following their arrival time such as new arrival, six months to two years, greater than two years, prior experience as an EM-CWs, etc. Furthermore, it is also suggested to conduct longitudinal studies to understand the impact of stressors and stress on the performance of EM-CWs varied over time.

CONCLUSION

This study has identified the acculturation stressors, three stress symptoms, and three task performance of EM-CWs for stress management. The focus group discussions were conducted with three major ethnic minority communities separately. To get a systematic qualitative data, the discussions for all groups were arranged in an identical structured framework, and contextual analyses were adopted for all collected data. Due to *acculturation stressors*, i.e., *strange feeling*, *adjustment*, *new environment*, and *difficulty to find a job*, EM-CWs experienced *anger*, *tension*, and *fear*, and consequently reduced their performance, including *working speed*, *making mistakes*, and *losing focus*.

To improve the performance of EM-CWs by managing stress, some recommendations were made including the promotion of social cohesion, provision of career development support, such as trade skills training, language courses, mentorship schemes, and so on. Suggestions for the future studies have also been proposed, including investigation of more variables related to EM-CWs, and adoption of quantitative research methods. These results form a basis for future studies on stress management of EM-CWs.

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A STUDY OF EXPOSURES TO ERGONOMIC INJURY FROM MOVING HEAVY OBJECTS MANUALLY ON CONSTRUCTION SITES

Fidelis Emuze

Central University of Technology, Free State South Africa

Correspondence: femuze@cut.ac.za

ABSTRACT

This study was focused mainly on the ergonomic issues and injuries experienced when manually lifting, carrying and/or removing heavy objects on construction sites. The aim of the reported study was to answer the question: Why do ergonomic injuries, caused by lifting, carrying, and removing heavy objects, persist on construction sites? Primary data were collected for this phenomenological study during access granted to six construction sites in Johannesburg, South Africa, to conduct interviews. Six construction sites were visited during the study and appointments were scheduled to conduct face-to-face interviews with personnel who were involved directly in work related to the research topic. Five people participated from each construction site, which gave a total of thirty people who were interviewed during the study. The data were analysed thematically based on the interview protocol. The findings revealed that wearing personal protective equipment (PPE) is emphasised in current health and safety methods stipulated in legislation, which is the least intervention if the general principles of prevention (GPP) are considered. The skewed reliance on PPE accounts indirectly for why ergonomic exposures continue to be a challenge on the construction sites visited. Contractors, together with construction workers, agree that current methods that rely on PPE alone are not effective in reducing ergonomic injuries, specifically those resulting from manually lifting, carrying and/or removing heavy objects on construction sites. It was concluded in this paper that ergonomic injuries, caused by manually lifting, carrying and/or removing heavy objects, persist on construction sites because legislation is not viewed as a minimum when addressing health and safety concerns. It was recommended that the method statements and construction practice be reviewed to consider ergonomic injuries caused by manually lifting, carrying and/or removing heavy objects on construction sites.

Keywords: construction ergonomics, cumulative trauma disorders, health and safety, musculo-skeletal disorders, repetitive motion injuries.

INTRODUCTION

Work on all construction sites is hazardous owing to the nature of the activities involved. The risk of a fatality is five times higher on a construction site than it is in manufacturing, and the risk of a major injury is two and half times higher (Behzadan and Bastani, 2014). In several sources,



including the Health and Safety Executive (HSE, 2002), it is stated that construction could be dangerous because work-related illness and injuries remain higher than other occupational industries.

From site visits, it has been found that workers suffer from musculo-skeletal disorders (MSDs), cumulative trauma disorders (CTDs) and repetitive motion injuries (RMIs) (Reese, 2016). It has been observed that these injuries occur because construction workers most frequently are involved in the manual lifting of heavy objects from the ground to knee, waist, arm, and shoulder heights, and even to overhead heights. They spend a great deal of time lifting, holding, carrying, pulling, or pushing loads of material. For example, manual mortar mixing requires carrying and lifting cement bags which weigh approximately 36-45kg each and pushing a wheelbarrow full of river sand. Furthermore, masonry work involves lifting concrete blocks which weigh approximately 16kg each, at or above shoulder height or even at overhead levels. As a result, construction workers tend to be affected by ergonomic injuries, which cause them to suffer mostly from back pains, neck and shoulder strains, and spine dislocations. Once a worker suffers ergonomic injuries, their quality of life becomes compromised. These injuries also have an impact on the finances of construction companies. Although, safe working procedures (SWPs) that deal with operation, maintenance and inspection are in place, the occurrence of ergonomic injuries persists and continues to be a major, problematic issue among people in construction (Reese, 2009). Thus, MSDs, CTDs and RMIs lead to reduced quality of life and permanent disabilities among workers while their employers face skill shortages and constrained productivity.

Therefore, the aim of this study was to investigate the quality and effectiveness of current methods implemented by contractors and construction workers to reduce ergonomic injuries on construction sites, and to examine the types of ergonomic injuries resulting from manually lifting, carrying and/or removing heavy objects on construction sites. Feedback was obtained to the primary research question: Why do ergonomic injuries, caused by lifting, carrying and or removing heavy objects, persist on construction sites? The study has the potential to contribute to the body of evidence available about the causes of the persistence of ergonomic injuries in construction, specifically during projects in South Africa. In particular, the deficiencies of the prevention measures have been noted. The findings of the study might also assist in developing suitable guidelines for construction practice to minimise ergonomic injuries.

ERGONOMIC ISSUES IN CONSTRUCTION

Ergonomics in industrial worksites, by definition, means fitting the workplace to the worker (Reese, 2016). It can be defined also as movements within the workplace, being either: handling objects, tools, and machinery; working in compromised positions; climbing and descending heights; carrying heavy materials around; bending and twisting the body; or lifting arms and shoulders for long periods. Ergonomics means that the work environment is designed to fit the workers through direction, controls, signals, schedules, and machine interface, for example.

Ergonomic-related conditions are clear on construction sites. Workers are involved in lifting heavy objects from the ground to the height of their knees, hips, arms, shoulders and even up into the air. For example, the installation of windows and door frames and sheet materials



requires construction workers to lift and carry heavy objects. Manual handling of material and other lifting activities is an inseparable part of construction work. Common effects of injuries associated with such work activities include neck disorders and forceful arm exertions, cervical spondylosis and, in some cases, muscular disorders such as tense neck syndrome (Nimbarte et al., 2010). Routine construction work requires repetitive lifting of objects to shoulder height, and the sustained activity in neck muscles during these tasks can be linked to reduced blood flow, repetitive loading of tendons, rupture of the muscles' z-discs, and contractile forces acting on the cervical spine (Nimbarte et al., 2010).

Top ergonomic problems are working in the same position for long periods, bending and twisting the back in an awkward way, working in awkward or cramped positions, working when injured or hurt, and handling heavy materials or equipment (Smallwood, 2017). The nature of certain tasks and situations dictates the application of muscle power, especially when handling material in narrow and confined spaces or performing maintenance activities. The relationship between insufficient strength and injury has been widely acknowledged in activities such as the manual handling of material and those requiring the use of hand tools (Nimbarte, 2010). Also, prolonged exertions and working in the same position for long periods can result in cumulative fatigue. Awkward, extreme, and repetitive postures can also increase the risk of MSDs.

Manual handling of heavy material, as well as work activities in constrained seating might result in an increased risk of low back pain, but these seated work activities might only result in increased risk when exposure is for a long duration (Van der Molen, 2018). The nature of repetitive or prolonged sitting is also assumed to be crucial. However, limited attention has been paid to assessing exposure to movements and exertion of force, although there are indications that posture is of approximately the same significance as risk factors related to movements and exertion of force during the manual handling of materials.

However, the movement of body parts is very difficult to estimate from outward appearance. Only by observation of videos in slow motion and by direct methods of measurement, either at work or in the laboratory, can one or more of the dimensions of exposure to movement be assessed accurately (Van der Molen, 2018). For the assessment of forces exerted, observational methods rely heavily on the weight of objects being either lifted or lowered, which indicates the level of the force exerted. In the case of carrying and removing, the applied force can be estimated most accurately by the weight of the object being carried.

ERGONOMIC RISK FACTORS

Ergonomic risk factors are the characteristics of a job that results in bio-mechanical stress on the body. The risk factors vary according to different jobs and tasks, but the greater the exposure to these risk factors, the greater the probability of ergonomic injury. Reese (2016) noted that ergonomic risk factors are synergetic elements of MSDs. The risk factors include force, vibration, repetition, contact stress, awkward postures, cold temperatures, and static postures, as listed in Table 1.

The risk factors such as force and repetition affect various parts of the body. For instance, disorders or injuries affecting muscles, tendons, joints, ligaments, and bones are mainly caused by mechanical overload of biological structures. Overload of tissues results from high intensity forces acting on and inside the body (Luttmann, 2013). Furthermore, the duration of exposure is

a significant factor in the development of MSDs. The duration of exposure is determined by the number of repetitions per unit time, as well as by the total exposure time (Luttmann, 2013). According to Luttmann (2013), the factors influencing ergonomics are high forces resulting from lifting, carrying, pushing, and pulling heavy objects in the workplace, high repetition frequency, long duration of force execution, unfavourable posture, uninterrupted muscle force exertion, and/or working with vibrating machines. Lifting, carrying, and removing heavy objects during construction work require high activation of the musculature of the arms of the person bearing the load. Therefore, maintaining unfavourable body postures for a long duration might be associated with long-term activation of certain muscles, which might lead to muscular fatigue and considerable reduction in the blood circulation (Luttmann, 2013).

Table 1: Tasks and their ergonomic risk factors linked to moving objects (adapted from Reese, 2016)

Task	Heavy objects or people moved on construction site
A	Force
B	Repetition
C	Awkward postures
D	Static postures
E	Contact stress
Task	Horizontal reach (distance from hands to grasp object) is long
A	Force
B	Repetition
C	Awkward postures
D	Static postures
E	Contact stress
Task	Objects or people are moved over a significant distance on site
A	Force
B	Repetition
C	Awkward postures
D	Static postures
E	Contact stress

ERGONOMIC INJURIES LINKED TO MOVING OBJECTS

Nerve entrapment, which is a medical condition caused by direct pressure on a nerve, also might result from the build-up of pressure on the median nerve of construction workers because of carrying loads and gripping for a long time. According to Simoneau et al. (2013), carpal tunnel syndrome is an affliction of the nerves that are compressed, generally by the swelling of surrounding nearby tendons in a limited internal body space that constitutes the carpal tunnel. The affliction of the nerve causes numbness and muscle weakness. Simoneau et al. (2013) state



further that carpal tunnel syndrome is unique in that it is more painful at night, when the swelling is at its peak, and sufferers are often awakened by the pain.

Martmo (2009) states that heavy lifting increases the risk of back pain, which can be disabling. The back is a complex structure of bone and muscle, supported by cartilage, tendons, and ligaments, and fed by a network of blood vessels and nerves. The back, especially the lumbar region, or lower back, bears much of the body's weight during walking, running, lifting, and other activities (Luttmann, 2013). A medical definition of back pain, in both the lower and the upper back, includes conditions affecting the bony spine; discs between the vertebrae; ligaments around the spine and discs; spinal inflammation; spinal cord and nerves; muscles; internal organs of the pelvis, chest, and abdomen; tumours; and the skin. According to Luttmann (2013), during holding and removing of heavy loads, high forces affect the skeletal system, and the risk of acute overloading and damage might result. Luttmann (2013) states further that heavy load being carried for a long period of time might cause or promote degenerative disorders, especially in the low back area.

In relation to spine dislocation, researchers show that poor heavy-lifting techniques might increase the risks of developing spinal stenosis, a herniated disc, muscle injuries and other spinal injuries that might also cause injuries to other areas of the body, such as the ribs, thus leading to permanent disability. Injuries to the cervical 1 and 2 (C1 and C2) vertebral levels are the most severe of all spinal cord injuries and might result in complete paralysis. According to Robertson and Ryan (2012), when the cervical spine is dislocated below C2 level, further injury to the spinal cord occurs by sagittal deformation, and the severity of the damage is probably proportional to the compression at the time of injury. Robertson and Ryan (2012) state further that such compressions are aggravated by the narrow spinal canal. Therefore, this could mean that, during the heavy lifting and carrying of objects, compression of muscles occurs, thereby causing a narrowing of the spine canal.

Another injury linked to moving heavy objects is cervical spinal cord injury (CSCI), which might result in hospitalisation, rehabilitation, and loss of employment. These injuries might vary from partial to complete loss of upper and lower limb function (James, Harrop, Ashwini, and Alexander, 2009). According to Beatson and Force (2015), it is possible to recognise an unstable dislocation of the cervical spine by studying the initial lateral radiograph. Beatson and Force (2015) emphasise further that, when a patient with an injury to the head or neck is admitted to hospital, a lateral radiograph of the neck must be taken. If this indicates that one vertebral body has dislocated forward onto the next below it by less than the antero-posterior depth of the vertebral body, there is a unilateral facet dislocation.

RESEARCH METHOD

Interpretivism was the research philosophy adopted for this study. Researchers often choose this philosophy to understand the experiences of people. It involves the qualitative method of social research to study how people interpret and logically understand their experiences and the world in which they live (Walliman, 2011). The qualitative method, which is generally a research strategy that is focused on words and languages rather than numbers, was used (Hammersley,



2013). Primary data for this phenomenological study were collected during access granted to relevant construction sites in the Gauteng Province of South Africa. Gaining access to relevant construction sites was not easy. However, six construction sites were visited during the study to schedule appointments to conduct face-to-face interviews with personnel who were directly involved in work related to the research topic. Five people were interviewed from each construction site, which meant that a total of 30 people were interviewed during the study. The interviewees were willing to provide accurate information to the best of their ability. Some respondents were contacted by telephone and emails to answer questionnaires.

Interviews were conducted with front-line people on construction sites, including general workers (seven), engineers (two), H&S officers (ten), foremen (four), quantity surveyors (two), project managers (four), and other professionals (one). Gender representation among the interviewees was 60% male and 40% female. The data showed that the interviewees were likely to be familiar with the topic because only four of them had less than five years' work experience on construction sites. The interviews were less than an hour in duration and were conducted in English and translated into local dialects, such as Sesotho and IsiZulu, when requested by interviewees. All interviews were conducted personally by the researchers who were knowledgeable about the phenomenon.

Before the interview began in August 2017, all participants were informed about the survey questions and the expected duration of the interview. Each interviewee received a cover letter, containing a short survey, with the reasons for the survey and additional information. In this way, semi-structured interviews were conducted, and responses were handwritten according to an interview protocol that was created while the interview was ongoing. The protocol consisted of four themes based on the research objectives. The data were analysed in a thematic manner based on the interview protocol. Examples of the interview questions is provided in Table 2. The questions were pre-tested with peers and academics before the start of the field work to ensure validity. More importantly, one-to-one correspondence between the questions and the ability of respondents was ascertained. The procedure resulted in separate questions for site management and general workers as illustrated in Table 2.

Table 2: Examples of the interview questions

Questions for Site Management	Questions for General Workers
How does the organisation measure ergonomic injuries?	Have you received any kind of training or education about ergonomic safety on construction site?
At what stage of development is ergonomic safety considered?	Are there any measures or precautions taken to reduce ergonomic injuries caused by lifting, carrying, and removing heavy objects on construction sites?
What ergonomic injuries result from lifting, carrying, and removing heavy objects on construction sites?	Have you or your fellow colleague suffered an ergonomic injury caused by lifting, carrying, and removing heavy objects on



	construction sites? If so, what was the type of injury
What are the most effective measures in place to manage ergonomics on site?	How do you and your employer collectively reduce ergonomic injuries on sites

RESULTS FROM THE INTERVIEWS

The textual data that emerged from the analysis were arranged in themes.

Theme 1: Perspectives on ergonomic injuries on construction sites

Managerial perspective

According to the managerial perspective, the current health and safety policies were not as effective as they ought to be. Most of the interviewees in management claimed that they arranged an ergonomic training session for their workers prior to the commencement of each project. Such H&S training included safety awareness, posters, toolbox talks, risk assessments, regulations, as well as lessons from previous incidents. Approximately 60% of management stated that ergonomics was considered from site establishment to project finish. They also stated that ergonomics is measured and managed through the risk management process.

Site management stated further that the most effective measure to manage ergonomics on construction sites was to ensure the “step-by-step” monitoring of projects by the risk assessment team (construction managers, SHE officers, construction supervisors, as well as technical people with knowledge and experience of a specific field of activities). According to some of the interviewees, monitoring of the activities was vital, since not adherence to any control measure might cause incidents. They also stated that changes in the current H&S policies should be made as part of the reviewing process to equip risk assessment teams to provide qualitative training to the workers.

General workers’ perspective

General workers were interviewed to obtain their views as they were most directly involved in work related to the research topic. According to most of them, reviewing the current policies was a necessity. They stated that H&S measures and procedures were adhered to, and yet ergonomic injuries still occurred.

Some general workers stated that construction itself is a very dangerous occupation. Most of them believed H&S training provided to them was insufficient and ineffective. They also stated that, for instance, there were no training programmes or precautions taken to address working in confined spaces, as well as repeated activation of the same muscles without relaxation. Some general workers (five) perceived that either legislation or regulations or their management was providing them with very little training as far as their ergonomics was concerned. They stated



that what seemed to take priority was their wearing of personal protective equipment (PPE), and no other measures.

Theme 2: Severity of ergonomic injuries caused by moving heavy objects

According to both management and general workers, ergonomic injuries cause serious damage to the human body and result in permanent disabilities. Some of the general workers interviewed also testified from their own personal experience, where some claimed to have been very fortunate to survive such injuries. The workers also claimed to know colleagues who still suffer from ergonomic injuries. According to the interviewees, tasks such as lifting and carrying heavy objects might result in spinal cord damage, since a worker must bend and straighten up again while carrying a load. This might cause permanent damage to a person's spinal cord and the person might end up in a wheelchair permanently. They stated that hands and shoulders could also be damaged severely because some activities on construction sites require loads to be carried above shoulder and head level. This might place great strain on the shoulders, which might also affect the neck, thus resulting in severe neck damage.

Theme 3: Perspectives on way to reduce ergonomic injuries on construction sites

Both site management and general workers were of the same opinion that current H&S policies were not of much assistance in reducing ergonomic injuries on construction sites. They claimed that they adhered to all the regulations stipulated in legislation, yet the problem persisted. Site management stated that, although they believed legislation should be reviewed, they were still putting much effort into ensuring that the workers' H&S was a priority. They stated that they were adhering to the H&S training and precautions provided to them by H&S officers and other experienced people on sites. They also stated that previous incidents were of great significance in educating the workers, to prevent such incidents from occurring again.

About 85% of general workers of the view that the existence of technology should be put to good use by improving the way some activities were carried out in construction operations, such as the use of machinery instead of manual handling of materials and other heavy objects. They believed that ergonomic injuries would be reduced if machines replaced people, and many workers would be able to work for many years without their physical condition being compromised.

Outcome of site observations

On some of the construction sites, permission was granted for interviews and observations, as well as taking photographs. Field notes were taken based on the observations. Each construction worker was viewed from behind, as well as from the side, when lifting, carrying, and removing heavy objects on site. After lifting, carrying, or removing heavy objects, each worker would take a long time to return to their normal posture after bending, after which they would stretch their arms and fingers as a sign of relief. Most of the workers would also touch their lower backs after carrying heavy objects, as a sign of pain and strain. These observations indicated that ergonomic injuries, caused by lifting, carrying and/or removing heavy objects on construction sites, had



serious effects on the human body and, if not dealt with, could result into permanent disabilities among the workers on the project sites visited.

DISCUSSION

Both site management and general workers expressed the opinion that current legislation and approaches were of no assistance in addressing ergonomic issues and, therefore, should be revised to prevent injuries. Beyond these gaps in regulations and approaches, there was a need to reduce exposures to ergonomic injuries on site. Possible solutions can be categorised into eliminate the hazard (engineering controls); improve work policies and procedures (administrative controls); and provide PPE (Reese, 2016: Occupational Safety and Health Administration [OSHA], 2018).

As opposed to targeting the use of PPE alone, the best solution involves a combination of two or more approaches. For example, engineering controls enable site management to eliminate hazards on sites. Responsible people on site can change tools, equipment, job design and work area to eliminate hazards. In terms of moving heavy objects, the provision of carts for transportation and use of mechanical hoists can eliminate the hazard. The next step is to improve work policies and procedures, referred to as administrative controls. Administrative controls will, *inter-alia*, include the training of workers on safe working postures, lifting techniques, and safe use of lifting and carrying devices (Reese, 2009, 2016; OSHA, 2018). While engineering and administrative controls are being finalised for implementation, PPE can be deployed to reduce risk and exposure; for example, shoulder pads can be used to cushion heavy loads carried on the shoulder.

The solutions to ergonomic problems should be reviewed continuously. The solutions would be more effective if implemented as part of a comprehensive ergonomic programme, that is supported by management commitment, worker involvement, training and education, job analysis and control, hazard identification, prevention, reduction, and elimination (Reese, 2016). The use of an ergonomic hazard identification checklist by site management and the workers, as part of a comprehensive programme, will also help to reduce harm to people.

CONCLUDING REMARKS

Construction activities performed by workers are mostly repetitive and physically demanding. The execution of such activities in awkward postures strains body parts and can result in injuries or, in severe cases, permanent disabilities. Based on the findings of this study, it was concluded that ergonomic injuries, caused by manually lifting, carrying and/or removing heavy objects, persist on construction sites because of the skewed view that relying on legislation is the ultimate protection strategy. In response to the primary research question of why ergonomic injuries, caused by manually lifting, carrying, and removing heavy objects, persist on construction sites, it is argued that prevention techniques that go beyond compliance to legislation are required. The strategy requires an appropriate combination of engineering and administrative controls with the use of the required PPE.



In summary, the data obtained from interviews shared in this paper showed that there is a need to reduce ergonomic injuries caused by manually lifting, carrying and/or removing heavy objects on the construction sites visited. The insights also indicated that manually lifting, carrying and/or removing heavy objects on construction sites results in severe and chronic injuries, which might result in permanent disabilities among general workers. In addition, site management and workers must unlearn the notion that legislation and policy alone can address ergonomics issues on construction sites. As such, solutions to ergonomic issues rely on a hierarchy of hazard controls in which the use of PPE is the minimum, in terms of consideration.

However, it is noted that the reported research was focused only on ergonomic issues in relation to heavy objects being lifted or moved by construction workers. The limited scope justifies a call for a broader study in future. Future research could lead to the development of theory and testing of hypotheses using a quantitative method or mixed methods.

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CONFLICT OF INTEREST

No conflict to be disclosed regarding this paper

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Risk myopia among UK construction workers: Refining the Prescription for our Safety Glasses

Ilya Andreev, Fred Sherratt

Anglia Ruskin University, Essex, UK

Correspondence: fred.sherratt@anglia.ac.uk

ABSTRACT

Risk assessment and the consequential implementation of control forms the foundation of health and safety legislation in the UK. However the process of risk assessment inevitably remains subjective. Although training exists, it has not yet effectively eliminated risk recognition issues and accidents where it is a contributory factor still occur, suggesting a level of 'risk myopia' among the workforce. Knowledge of the form this myopia takes, and how risk recognition is influenced by other factors, could improve understandings of how construction workers experience risk. A survey of n=30 construction site workers explored the extent to which different factors influenced how they: perceive risk; accept risk; question the risk assessment; ignore infringements; and disregard the risk assessment mitigations. Descriptive and inferential statistical analysis revealed that trust is critical to risk perception, and identified a risk myopia around perceptions relating to the natural and man-made environments. Worker age and the years worked in the industry were found to significantly influence risk perception, whilst job role was only influential on some aspects whilst questioning risk, ignoring infringements and personal disregard of risk protocols were not influenced by job role, suggesting workers and supervisors are more similar than dissimilar in these aspects of risk perception. Forms of 'risk myopia' do exist on sites, which should be acknowledged by managers when assessing work tasks and worker compatibility, and further research undertaken to better understand and so address it in practice.

Keywords: safety, risk perception, risk-myopia, workforce

INTRODUCTION

Construction work is often risky, and as a consequence the industry has high rates of occupational injury and illness compared to many other sectors (HSE 2021). Risk assessment and management is unsurprisingly a core tenet of occupational health and safety management in the global construction industry, and in many countries is enshrined in law. For example in the UK the Management of Health and Safety at Work Regulations 1999 require a suitable and sufficient risk assessment of all the risks to the health and safety of employees that they are exposed whilst they are at work.

Academic researches of risk management and risk-taking often focus on the range of proximal and distal factors which predispose workers to these behaviours (Choudhry and Fang 2008) but more infrequently explores the relationships between them (Harvey 2018). Renner et al (2015) state that an important determining factor of people's behaviour is risk perception; how individuals think and feel about the risks



that they face. Risk perception itself is rarely entirely rational, and people tend to use a mixture of their physical perception, cognitive skills and emotional appraisals in order to determine the likelihood of harm befalling them (Baron et al 2006). Thus the process of risk assessment inevitably remains subjective, not only when it is formally undertaken in the production of the risk assessment itself, but also on an informal and near-constant basis by those who sign up to follow them in practice (Rawlinson and Farrell 2009). Site workers are expected to be able to spot hazards as they emerge in the dynamic site environment, evaluate the risks and take action accordingly. This can create problems for supervisors and managers when putting people to work as worker risk perception may be lacking and poor risk perception can lead to accidents. But although training in risk perception exists, it has arguably not yet effectively addressed risk recognition issues, as accidents in which it is a contributory factor still occur, suggesting a possible form of 'risk myopia' among the workforce. There remains a gap in our knowledge as to how such subjective positions are developed and which factors have most influence. This study aims to begin to explore risk perception among construction workers, specifically how they respond to the various factors that influence risk perception, and how they feel their subsequent actions could be affected. In doing so, it also explores how these actions are further affected by worker age, years worked in construction and their job role in terms of supervisory responsibilities. Increased and enhanced knowledge of the form any construction site risk myopia takes, and how risk recognition is influenced by other factors, will help improve understandings of how construction workers experience risk and be able to inform improved interventions to manage it in practice.

CONTEXT

Risk Perception in Construction

Albert and Hallowell (2012) attribute the high levels of worker accidents and injuries in construction to a large numbers of workers lacking adequate training or experience in recognising or responding to on-the-job hazards and risks. There tends to be a misconception in construction that creating a multitude of safety programs and enforcing their implementation will inevitably yield safer conditions for workers (Hallowell and Gambatese 2010). Albert et al (2014) add that most safety management programs and systems are actually created and with the inherent notion that the workforce can easily identify risks and hazards before they occur, however their research shows that construction workers do struggle with appropriate hazard and risk identification.

Time served on site can enable learning, as workers have been found to recognise these more commonplace hazards and risks in their immediate work environments, such as working at height, as opposed to more unusual hazards (Albert, et al. 2017; Liao et al 2021). Although experience does not inevitably result in high hazard and risk identification as Perlman et al (2014) found in their study, in which a sample of workers with many years of experience were only able to identify a similar number of hazards as a sample university students with no or little construction site experience. Although despite the failings in risk perception training in construction, it arguably remains an improved situation to having no training at all (Perlman et al 2014).

Human Factors and Risk Perception

Risk and hazard training for construction often focuses on the most common or most potentially injurious hazards and their associated risks as found on sites, and these are themselves can unfortunately be readily identified by the damage they cause to the workforce by accident statistics. However, there are many



human factors that influence how workers respond within these contexts: associated with the individual, the work and the organisation.

The Individual

Hazards and risk is part of our everyday life and in deciding how to manage those risks people apply value judgements and mobilise heuristics and they also do the same at work on construction sites (Sprinkle 2018). Alongside factors such as age, work experience and have influence, with younger workers more at risk (Ricci et al 2019), heuristics are cognitive shortcuts that individuals utilise to make decisions quickly and overcome gaps in knowledge based on their emotional state. Newkirk (2014) indicates that heuristics or mental shortcuts have their place in fast decision making when applied to find solutions to smaller problems however, when faced with complex issues they often lack the correct analysis need to make those decisions. Indeed, Tversky and Kahneman (1974) hold the view that heuristics are an erroneous decision-making process that leads individuals coming to decisions that defy statistics as they are based on emotion and not logic. For example, an individual seeing two equally dangerous situations would be more inclined to conclude that one is more hazardous than the other based on their personal experience or information that they possess on that particular hazard, all while not having enough information to compare both hazards and come to a logical conclusion (IOSH Magazine 2019).

A further consideration here is that of salience bias, mobilised when an worker is deciding on which hazard poses a greater risk (Spitmaan et al 2019). Salience bias is our propensity to focus on more noteworthy information that grabs our attention, which in turn can lead us to overlook other and more crucial pieces of information (Tiefenbeck et al. 2018). As salient information is not always the most precise, this can lead the worker to overestimate the occurrence of atypical dangers and underestimate threats that are much more common (Taylor and Fiske 1978).

The individual's own experiences can also impact their risk perception. For example, personal fears have influence, such as a fear of heights. Events that invoke dread, such as drowning or being eaten alive, scare people more than those that do not (Slovic and Weber 2002), and hazards with the potential to kill you in a dreadful way evokes more fear and thus alternative behaviours around them, than one that kills more benignly. This can also be associated with contemporary media and the publication of recent events, indeed people have been found to evaluate risks through inferences made from media coverage (Paek et al. 2017) and the more we are aware of a risk, the more we are likely to be concerned about it (Ropeik 2011). Risks that affect people personally are also more frightening than those that affect strangers (Slovic and Weber 2002). Any risk seems larger if you think you or someone you care about could be injured, which itself explains why statistical probability is often an ineffective form of risk communication as a risk of 1 in 1,000,000 can still seem threatening if an individual can see they could be 'the one', explaining why the only acceptable level of risk to many people is zero. (Ropeik 2004).

The Work

Workers see familiar or voluntary risks as less serious than risks that are new or imposed upon them (Tulloch and Lupton 2003), as a risk that is chosen seems less dangerous than a risk that is imposed (Ropeik 2004). Slovic and Weber (2002) further state that people are less concerned about risks they incur themselves, than the ones that others enforced on them. If a worker volunteers for a risk-evident job, he is less fearful than if he was selected to complete it (Ropeik 2011). Rational choice theory (RCT) shows



that a person is more likely to understand and model their behaviour to be health and safety compliant if they have a choice in whether or not to undertake that risk (Kahneman 2012).

Having perceived control over the outcome also affects that person's perception of the risk posed to them. This concept can be extrapolated to feelings of power, as Mindell and Birley (2020) when they say that individuals with power rank hazards as being of lower consideration, whereas individuals with less power rank those same hazards as a much higher risk. A further related concept is that of time. Risk perception is subjective in relation to time, and based on an individual's preconceptions (Mindell and Birley, 2020). Hazards that kill people quickly evoke more fear than hazards that may take more lives, but over a longer space and time (Ropeik, 2004). Uncertainty also creates fear, and thus a predisposition to risk aversion (Ropeik 2004), whilst the familiar can lead to complacency. This translates into the natural and man-made environments, as although the natural environment presents many dangers, beyond dramatic events such as being eaten by a lion, most people perceive natural risks as relatively benign (Slovic and Weber, 2002) in comparison to those that are man-made.

The Organisation

When workers trust the people that are either informing them about the risk, exposing them to the risk, or creating the process to protect them from the risk, the less afraid they are and the more likely they are to go along with it (Ropeik 2011). Lekka et al. (2012) emphasize the importance that trust plays between a manager and worker, whilst Rowe and Guerrero (2015) also suggest that a person is more likely to undertake a task if they trust the person assigning it. More subtly, Savadori et al. (2015) note that when an employee is positively predisposed to an organisation and is tasked with evaluating their own risk, they will ultimately rate the risk level as low, conversely individuals who have a negative outlook on their relationship with their organisation will rate their risk level as high. This trust relationship is also developmental and can change for the better or worse, for example if a worker makes a suggestion about health and safety and the manager listens, then the worker is also more likely to enforce the change themselves (Luria et al. 2008). Trust in both the individual and organisation is therefore very important in all dealings that involve risk and in the workplace in general (Hughes et al 2018).

Trust is itself based on a number of factors. For example, it has been found that if a construction supervisor has sufficient and demonstrably competent knowledge, people are more likely to trust them in regard to their own health and safety (Hardison et al., 2014). Harvey (2018) further substantiates this statement, adding that effective communication further enhances that trust, suggesting another necessary skill for site leadership to enhance risk management. Indeed, trust in leadership has also been associated with reduced injury rates, as safety-related interactions are subsequently given more importance (Zohar and Luria 2003). Mutual trust, respect and obligation between leaders and subordinates, is associated with good safety communication and thus positive safety outcomes (Kath et al. 2010). Trust is therefore not only a key factor in individual risk perception but one that can easily change in accordance with the continuing lived experiences that surround worker-supervisor interactions, and the continued use of effective communication in that process.

Summary

Human Factors considerations of risk bring together myriad aspects of influence, many that co-construct and develop certain perspectives of risk depending on the individual, the work and the organisation. In the construction industry, training has often focused on hazard and risk identification by workers, but a



consideration of Human Factors suggest the phenomenon is far more complex than can be remedied in this way. As Rawlinson and Farrell (2009) suggested training and education are unlikely to provide a solution as the complexities and personal influences that also affect risk perception are much more difficult to counter.

METHOD

This study begins to explore risk perception among construction workers, specifically how they respond to the various factors that influence risk perception, and how they feel their subsequent actions could be affected. It also examines how these actions are further affected by worker age, years worked in construction and their job role in terms of supervisory responsibilities. As this study sought to examine the relationships between variables, a quantitative approach was chosen. A sample of convenience was used, in part due to the exploratory nature of the work, and ultimately comprised 30 site workers and managers from one large site in the UK. This is an acknowledged limitation of this work, and prevents generalisation or the generation of robust recommendations, however it does provide insights as to the potential of this approach in the future.

The Survey Tool

A questionnaire survey was developed, incorporating the most prominent influential factors known to influence risk perception as identified through the literature review. The questionnaire was administered by the lead researcher in the site environment, which enabled them to confirm or explain any questions as needed. Biodata in the form of worker age, job role (worker/manager) and years worked in the industry was collected to enable enhanced data analysis. Overall, the sample was 100% male, with an average age of 36 and an average of 12 years' experience in the industry, although 7 participants had less than one years' experience in construction. A Likert Scale was used to explore the extent to which 15 elements identified from the literature affected the workers perceptions of risk within the workplace, running from Not at all (0); Slightly = 1; Moderately = 2; Considerably = 3; Extremely = 4, and with regards to: The workers perception of the risk involved; the amount of risk they will take on; the likelihood of them questioning risk protocols put in place; the probability of you ignoring infringements to risk protocols; the possibility of you disregarding risk protocols yourself. These five aspects are now referred to as the '5 Main Questions' for this study.

Data Analysis

MS Excel was used for the analysis undertaken. Descriptive statistics revealed the most and least influential factors among those identified in the literature. Inferential statistics were then used to test a number of hypotheses themselves developed to further explore how age, job role (worker or manager) and the number of years worked in construction also influenced these 5 Main Questions. For example, with regards to the relationship between job role and the likelihood a worker would question the risk protocols put in place, the hypothesis was framed thus:

- H_0 = A person's job role does not influence the likelihood of them questioning risk protocols put in place.
- H_a = A person's job role does influence the likelihood of them questioning risk protocols put in place.

Chi-Square and Degrees of Freedom are used to determine the p-Value, with a value of $p < 0.05$ to enable hypothesis testing and thus the potential to reject the null hypothesis (H_0) in favour of the alternative hypothesis (H_a) (Curran-Everett, 2009).

FINDINGS AND DISCUSSION

Table 1 shows the most influential factors as associated with the affiliated worker risk management behaviours as defined by the 5 Main Questions.

As shown, trust in the person informing the worker about the risk / exposing them to the risk / or creating the process to protect the worker from the risk affect was deemed by the sample to be the most influential factor with relation to all five of the Main Questions asked. Trust in the company is also a prominent factor across the 5 Main Questions. This is to be expected as the literature also highlighted that trust is very important in all dealings that involve risk and in the workplace in general (Hughes, 2018). However this factor is not often explicitly considered within risk management studies, perhaps because the underlying factors are also complex and rely on further subjective considerations around competence (Hardison et al., 2014) and communication (Kath et al. 2010). The role trust plays in occupational safety management should arguably not be underrated, and further work is required to explore how best trust and its antecedents can be best developed to further enhance safety management and leadership practices where possible.

Overall Influential Categories divided into the five main questions								
Question	Top 3 Categories	Average Score Out of 4	Percentage of Influence		Question	Bottom 3 Categories	Average Score Out of 4	Percentage of Influence
The person's perception of the risk involved	Trust (Person)	2.26	56.50%		The person's perception of the risk involved	Volunteering	0.97	24.25%
	Know Person	1.94	48.50%			Fun Factor	1.19	29.75%
	Trust (Company)	1.87	46.75%			Natural Environment	1.23	30.75%
The amount of risk they will tale on	Trust (Person)	2.1	52.50%		The amount of risk they will tale on	Imagination	1	25.00%
	Trust (Company)	1.84	46.00%			Natural Environment	1.1	27.50%
	Control	1.84	46.00%			Fun Factor	1.16	29.00%
The likelihood of questioning risk protocols put in place	Trust (Person)	2.1	52.50%		The likelihood of questioning risk protocols put in place	Fun Factor	0.74	18.50%
	Trust (Company)	1.52	38.00%			Imagination	0.9	22.50%
	Man-Made Environment	1.45	36.25%			Natural Environment	0.94	23.50%
	Personally Affected	1.45	36.25%					
The probability of ignoring other people's infringements to risk protocols	Trust (Person)	0.84	21.00%		The probability of ignoring other people's infringements to	Uncertainty	0.45	11.25%
	Trust (Company)	0.71	17.75%			Man-Made Enviornment	0.48	12.00%
	Control	0.68	17.00%			Imagination	0.48	12.00%
The possibility of them disregarding risk protocols themselves	Trust (Person)	0.65	16.25%		The possibility of them disregarding risk protocols themselves	Uncertainty	0.29	7.25%
	Media Awareness	0.65	16.25%			Volunteering	0.39	9.75%
	Natural Environment	0.61	15.25%			Personal Fears	0.39	9.75%
	Speed	0.61	15.25%					
	Familiarity	0.61	15.25%					

Table 1: The most and least influencing categories associated with the 5 main research questions

Additional factors also reflect the wider risk management/perception literature. Control is seen as a highly influential factor when a worker is considering the amount of risk they will take on, reflecting other findings from research beyond construction (Ropeik, 2004). Interestingly, more workers feel they would question risk protocols put in place related to man-made risks, and disregard protocols themselves when



they were from the natural environment. This is an interesting insight, as although this does reflect the literature which notes natural risks are considered relatively benign (Slovic and Weber 2002), it raises specific questions for construction work where both worlds often collide. The weather is a known issue for the construction industry, from vulnerabilities to high winds and other extreme events to individual sunburn issues. The reproduction of wider risk perceptions around these phenomenon among the workers brings a further insight from these data as safety management, supervisors and workers should be mindful of the potential for this specific risk myopia within the workforce and look to ensure equitable natural hazards and associated risk are given the same attention and control as equivalent man made hazards and risks in practice.

The least influential factors saw more variation and thus less consensus between the respondents as a number of different factors were deemed the least influential for the 5 Main Questions by the participants. Interestingly, volunteering for the risk in the first instance was found to be the lowest influencing factor workers felt affected their risk perception, and the second lowest in the likelihood of them disregarding risk protocols. This challenges the literature which suggests that autonomy has significant influence on risk perception (Tulloch and Lupton 2003), but could reflect the nature of construction work and the lack of autonomy in work allocation therein. This could also go some way to explain why any fun in the task was not considered influential.

A pattern could also be seen in the natural and man-made environment influences on risk perception. The natural environment was rated the least influential in 3 of the Main Questions: perception of risk, amount of risk they will take on, and the likelihood of questioning protocols put in place. As discussed above, this factor is often devalued by individuals within the literature and so is to be expected, however the presence of man-made risks as a lesser influence on the probability of ignoring others' infringements of protocols is more of an anomaly. With regards to the likelihood of questioning risk protocols put in place, man-made risks were considered highly influential whilst natural risks were not. This may be in part due to a perceived lack of control of nature itself, but also reiterates the need for balance in risk management communications as within the site space both can be of equal concern.

The Influence of Age

The analysis of the data with regards to the influence of worker age can be seen in Table 2. As Table 2 shows, all findings for each of the 5 main questions find a P value lower than 0.05. The findings are therefore statistically significant, and we can reject the null hypothesis. Worker age does affect their perception of risk and the amount of risk that they are willing to take on, it plays a significant factor within a person's likelihood to question risk, whether they will ignore the infringements of others and could also disregard the risk themselves. This aligns to findings by others in this field, such as Ricci et al 2019.



Inferential Statistics Based on Age Divided into the 5 Main Questions						
	Chi-Square	Degree of Freedom	P-Value	Null Hypothesis	Results Statistically Significant	Sample Standard Deviation
Perceived Risk	39.5645	16	0.0009	Rejected	Yes	14.2215
Amount of Risk	53.6037	16	0.0000	Rejected	Yes	14.8099
Questioning Risk	63.9203	16	0.0000	Rejected	Yes	17.2892
Ignore Infringements	58.8569	16	0.0000	Rejected	Yes	28.9612
Disregard Risk Protocols	78.1646	16	0.0000	Rejected	Yes	31.9896

Table 2: The influence of age on the 5 Main Questions

The influence of Job Role

Analysis of the data with regards to the influence of worker job role can be seen in Table 3. This analysis shows that the null hypotheses cannot be rejected, as job role was not found to significantly influence worker risk perception for 3 of the 5 Main Questions.

Inferential Statistics Based on Job Role Divided into the 5 Main Questions						
	Chi-Square	Degree of Freedom	P-Value	Null Hypothesis	Results Statistically Significant	Sample Standard Deviation
Perceived Risk	2.5986	4	0.6271	Accepted	No	N/A
Amount of Risk	5.0755	4	0.2796	Accepted	No	N/A
Questioning Risk	11.4198	4	0.0222	Rejected	Yes	33.5169
Ignore Infringements	27.8618	4	1.3E-05	Rejected	Yes	65.8048
Disregard Risk Protocols	10.6237	4	0.0311	Rejected	Yes	70.753484

Table 3: The influence of job role on the 5 Main Questions

Questioning risk, ignoring infringements and personal disregard of risk protocols were not influenced by job role, suggesting workers and supervisors are more similar than dissimilar in these aspects of risk perception. However, job role does influence how individuals perceive the risk involved and the amount of risk they will take on. The usual hierarchical management structures found on sites could also have influence here, with workers feeling less able to refuse risk within their working day. This finding could also reflect a difference in confidence in the perception of risk, perhaps associated with differing levels of training and familiarity with risk management at the worker and manager/supervisor level.

Influence of Years Worked in Construction

Analysis of the data with regards to the influence of years worked in construction can be seen in Table 4. All result groups for the 5 main research questions have a P-value lower than 0.05. The results are therefore statistically significant, and we can reject the null hypothesis. The amount of years a person has been working in construction does affect their perception of the risk involved, aligning to findings of Liao et al 2021.



Inferential Statistics Based on Years Worked in Construction Divided into the 5 Main Questions						
	Chi-Square	Degree of Freedom	P-Value	Null Hypothesis	Results Statistically Significant	Sample Standard Deviation
Perceived Risk	37.6333	16	0.0017	Rejected	Yes	14.4827
Amount of Risk	47.9092	16	0.0000	Rejected	Yes	14.7253
Questioning Risk	61.2697	16	0.0000	Rejected	Yes	17.0538
Ignore Infringements	33.5209	16	0.0063	Rejected	Yes	28.9554
Disregard Risk Protocols	38.9303	16	0.0011	Rejected	Yes	31.7030

Table 4: The influence of years worked in construction on the 5 Main Questions

CONCLUSIONS

This study aimed to begin to explore risk perception among construction workers, specifically how they respond to the various factors that influence risk perception, and how they feel their subsequent actions could be affected. Findings reveal that trust in the individual but also the company are the most critical factors in worker risk perception. This was an interesting finding as trust is not a factor widely considered in risk perception work, nor is it something that can be provided through training. It is something inherent in the wider management and leadership of the site and thus could be developed through many other activities than safety management itself. A clear area of risk myopia found in data was in the ways the natural and man-made worlds were perceived in terms of risk, natural hazards deemed less influential than man-made. However on construction sites, where nature can make its presence felt through wind or sun, in ways that negatively impact workers and put them at risk, this is of concern. Both worker age and the years worked in the industry were found to significantly influence risk perception, job role was only influential on some aspects whilst questioning risk, ignoring infringements and personal disregard of risk protocols were not influenced by job role, suggesting workers and supervisors are more similar than dissimilar in these aspects of risk perception.

These findings can be used by managers when assessing work tasks and worker compatibility, but limitations of the study mean that further quantitative and qualitative research of this phenomenon amongst site-based workers is needed for enhanced insights. These can better inform risk management practices, and help develop training programmes in which a wider approach is taken to reduce the potential for risk myopia within the workforce and thus safer behaviours overall.

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THE GAUTENG GREEN AND NON-GREEN BUILDING'S ENVIRONMENTAL IMPACT AND POTENTIAL EFFECT ON THE HEALTH OF BUILDING USERS.

Jack Kianza

University of Johannesburg, South Africa

Correspondence : kianzajack@gmail.com

ABSTRACT

The most populated province in South Africa, Gauteng is home to 14,700,000 people and has the fastest-growing population. This population growth influences infrastructure, activities, and housing development. There are mega construction projects planned; other projects are already underway in the private and public sectors. Yet, many residents in the Gauteng province live in buildings that are considered environmentally unfriendly, creating unhealthy conditions for occupants. The estimates show that pollution alone kills almost 9 000 000 people a year worldwide and 20 000 people every year in South Africa. The country is currently facing a pollution challenge with approximately 500 million tons of carbon dioxide (CO₂) emitted yearly, mainly attributed to coal power stations that supply almost 90% of electricity to the entire country. Environmentally unfriendly buildings, usually considered non-green buildings, place a high demand for energy production done using coal. We have studied the level at which those non-green buildings contribute directly or indirectly to greenhouse gas emissions, compared to buildings designed following green principles, which contribute positively to the built environment. We further looked at the green and non-green buildings health implications after hearing from 60 building users about their sensations while spending more time in the office daily. In addition to data from building users indicating that green buildings are more comfortable, green buildings were measured as being better for the environment and guarantee happy people.

Key words: building's health implications, environmentally-unfriendly buildings, green building principles, mitigation, pollution challenge.

1. Introduction

There is a balanced relationship between people and buildings, so buildings serve as shelters for people, while on the other side, people who build buildings are in charge of their maintenance. Buildings must thus be constructed to serve not only as shelters but also to ensure the well-being of occupants.

Since the emergence of green buildings, they offer the frame conditions of a decent life for all inhabitants of cities, regions, and communities, including their physical and mental well-being.

This study aims to assess Green and non-green building's effect on occupants' wellness, looking at thermal comfort, CO₂, and energy consumption for buildings in South Africa.

1.1 What is a green building?

The World green building Council (WGBC)(2016-2021) defines a 'green' building as a building that reduces or eliminates negative impacts and can positively affect our climate and natural environment in its design, construction, or operation. Green buildings preserve good natural resources and improve our quality of life. Allen (2015) states that a green building reduces environmental impact by reducing energy use, water use, and environmental disturbances. With the potential for both positive and negative effects of buildings on people and the environment, the green building movement arose to minimize adverse impacts while



enhancing positive ones (Yudelso J., 2008). Green buildings minimize environmental impacts; they also reduce local effects on the building site by conserving energy and water; they prioritize the improvement of human health.

According to the Green Building Council of South Africa (GBCSA), many conventional buildings built in South Africa are Unsustainable buildings. Buildings classified as unfriendly to the environment contribute to greenhouse gas emissions and use high amounts of energy, resulting in increased energy production, which releases a considerable amount of CO₂ that pollute the air and contributes to climate change, which itself is associated with adverse health effects (Spengler J, Adgate JL, Busalacchi A, et al., 2011). Air pollution is caused by Green House Gas (GHG) emissions. It can cause premature death (Laden F, Schwartz J, Speizer F, et al., 2006), cardiovascular complications (Burnett R, Pope C, Ezzati M, et al., 2014), asthma symptoms (Habre R, Moshier E, Castro W, et al. 2014). CO₂ is one of the GHG but has not been considered a classic pollutant since CO₂'s ambient mixing ratios are not high enough to affect human respiration directly; however, its effects on temperatures affect meteorology, and both have an adverse effect on air pollution (Marc Z. Jacobson, 2008).

CO₂ levels and effects on adult in good health can be summarized to:

CO ₂ level	Effects
350-450 ppm	None, Normal outdoor level
< 700 ppm	None, Acceptable levels
700-1000 ppm	Complaints of stiffness and Ordos
1000 - 2500 ppm	General drowsiness
2500 - 5000 ppm	Adverse health effects may be expected
5000 - 10000 ppm	Maximum allowed concentration within a 8 hour working period
30000 ppm	Maximum allowed concentration within a 15 minute working period

Table 1 ASHRAE Standard, 2016

The term 'green building' describes a practice in the building industry that prioritizes environmental responsibility and resource efficiency over the entire lifecycle of a structure (U.S. Energy Information Administration, 2003)

As a result, occupant satisfaction is essential to enhance overall performance and profitability in office environments and commercial buildings. Therefore, it is essential to evaluate a building's overall performance from the perspective of its occupants.

Undoubtedly, research has primarily demonstrated the benefits of greens buildings on the well-being of the occupants. It is known that better quality of the indoor environment is always associated with better health outcomes, as shown by thirty years of public health research. Buildings can be harmful to us or suitable for our health depending on the living conditions they create (McNaughton et al., 2017, p. 179). Based on the standard values of CO₂ given by the ASHRAE standard (table 1), the CO₂ in buildings can affect occupant's health depending on the level.

1.2 What is health?

According to the World Health Organization (WOH), health is not merely the absence of disease or infirmity but a state of complete emotional and physical well-being (WHO 1948). Further clarifications were given in 1986 by the WHO states that "health is a positive concept emphasizing social and personal resources, as well as physical capacities," meaning that an individual's function in wider society is supported



1.3 Types of Health

Mental and physical health are two types of health that are often discussed; however, spiritual, emotional, and financial health is also part of the overall health since they improve physical well-being and are linked to lower stress levels by Medical experts. Good physical health is a state whereby the bodily functions and processes work at their peak. Good mental health refers to a person's physical, social, and mental well-being; according to the U.S. Department of Health & Human Services, mental health and physical health are essential for a whole, active lifestyle. The absence of depression, anxiety, and other disorders is insufficient to establish a good mental health state. The ability to enjoy life, feel safe and secure, bounce back after difficult experiences and adapt to adversity, etc., are also variables that significantly influence good mental health. We can notice strong connections between physical and mental health. If a person cannot complete his regular tasks due to a chronic illness, it may lead to stress and depression and further affect their body weight and overall function. All types of health are linked; it's, therefore, essential to look at an integrated approach to health rather than considering factors separately.

1.4 How do the thermal conditions of a building affect its users?

Five different conditions, among many others, can affect people's work in the office negatively:

1. Distraction in attention caused by thermal discomfort;

An individual's attention is distracted by thermal discomfort sensations resulting from heat stress or cold.

2. Intense heat decreases the state of activation of an individual

3. Office work is affected when the ambient temperature is slightly high and the same effects when there are rapid temperature fluctuations; and

4. The concentration of carbon dioxide in human blood may increase if the temperature rises, and it may cause headaches (L. Lan et al., 2011)

5. The temperature of the fingers decreases with the cold, which reduces manual dexterity.

(Wargocki and Wyon, 2017, p. 361)

2. METHODS

This study adopted the deductive method approach because it's more toward the quantitative analysis and saves time. The inductive approach requires more time as it doesn't lay on any theories. Another reason is that the summary of theories and hypotheses developed in the literature review is a solid background for testing in the discussions section, according to Saunders et al. (2007). The test can be applied in a numeric form and statistical in making statements about the data. Due to the limited time, the cross-sectional time horizons were convenient for this study.

Due to COVID-19 restrictions, limiting the numbers of workers in their workplaces, sixty (60) over an estimated population of seventy (70) workers were reached online and in their workplaces.

a) Building information

Buildings were chosen based on the following criteria:

1. Type of building: Commercial building

2. City: Johannesburg.

3. Building orientation: located in approximately the same geographical coordinates viewed from Google Earth,

4. Size of the office-building floor area: between twenty and fifty square meters.

Setting the above criteria was to have buildings with approximately the same features for accurate results. Commercial buildings were chosen because it is where people spend more time working. We looked at



buildings in Johannesburg because more and more people are moving into the city searching for economic opportunities. This migration situation places a high demand for social, public, and institutional infrastructures. This means that while the accommodation challenges are being attended to, issues related to the health, comfort, and safety of those meant to live in those buildings need to be considered. The same building orientation gives almost the same hours for daylight, which helps reduce energy consumption from lights during the day.

Fifteen buildings rated by the Green Building Council of South Africa were targeted. A prior contact was made to get the consent and reactions of workers for participating in the study. Still, the authorization to conduct the survey was only given by three buildings presented in Table 2. The total number of people working in the eight office buildings was 70; all received a consent form to sign for their participation and could withdraw their participation at any time. Sixty participants, 30 green building office users, and 30 conventional building office users have completed the Google form survey that consisted of a questionnaire on how they feel about thermal comfort and air quality. The winter and summer surveys were conducted in the winter and summer seasons respectively in the same buildings where sensors were deployed.

Type of building		Rating System	City	Building orientation	Size of the office-building floor area
Commercial with office blocks	Conventional	-----	Johannesburg	26 degrees 08'35''S; 28 degrees 01'15''E	20 to 50 square meters
Commercial with office blocks	Green	Green star rated by GBCSA	Johannesburg	26 degrees 11'38''S 28 degrees 08'19''E	20 to 50 square meters
Commercial with offices blocks	Green	Green star rated by GBCSA	Johannesburg	26 degrees 09'54''S 28 degrees 04'46''E	20 to 50 square meters

Table 2

b) Tools

Two sensors, SN10772349 product MX1102, manufactured by Onset Computer Corp., were deployed in two office buildings, the first in the conventional office building and the second in one green office building. We collected the data of the second green office building from the Building Management System. Sensors collected the temperature, carbon dioxide, and humidity in the buildings each hour during winter and summer to quantify their effects on occupants. It took 235 days and 23 hours to complete the data collection.

Besides the sensors, a survey was conducted in all eight office buildings. The criteria for choosing participants were inclusive. As mentioned in the introduction, the aim was to find out if the various characteristics of a building would respond to occupants' needs regardless of their sex, age, race, etc. Therefore, Adults men, and women occupants of green and conventional buildings and working for at least 6 hours every day could participate. Allowing people to participate in the survey was to find out



about symptoms, including their feelings, perceptions, and concerns about staying in the building, to support the measurable data obtained by sensors and compare the results with the literature.

3. Findings

3.1 Data from sensors.

Data collected are presented as followed:

Table 1 presents the data collected from the two green office buildings and one conventional office building. For the comfortable temperature, this is the number of times the sensor has shown a temperature at the comfort zone, meaning between 20 and 25 degrees Celsius and outside the comfort zone the temperature is uncomfortable; likewise, for relative humidity, the acceptable range is 30 to 60 percent (ASHrae standard 55, 2004). Finally, carbon dioxide (CO₂) is indicated by the number of times the value was less than 700 parts per million (ppm) and the one with a value greater than 700 ppm.

	Conventional	Green 1	Green 2
Number of time of Comfortable Temp, °C (20°C -25°C)	3687	4379	3816
Number of time of Uncomfortable Temp, °C	1976	1284	1847
Number of time of Acceptable RH, %	2650	4347	4338
Number of time of Unacceptable RH, %	3013	1316	1325
Number of time of CO ₂ less than 700 ppm	1376	5587	4151
Number of time of CO ₂ greater than 700 ppm	4287	76	1512

Table 3

ASHRAE Standard 62.1-2016: Acceptable CO₂ level < 700 ppm

3.2 SURVEY ANALYSIS

a. Temperature in winter

Survey question: How is the temperature in the office in winter?

Conv and Green

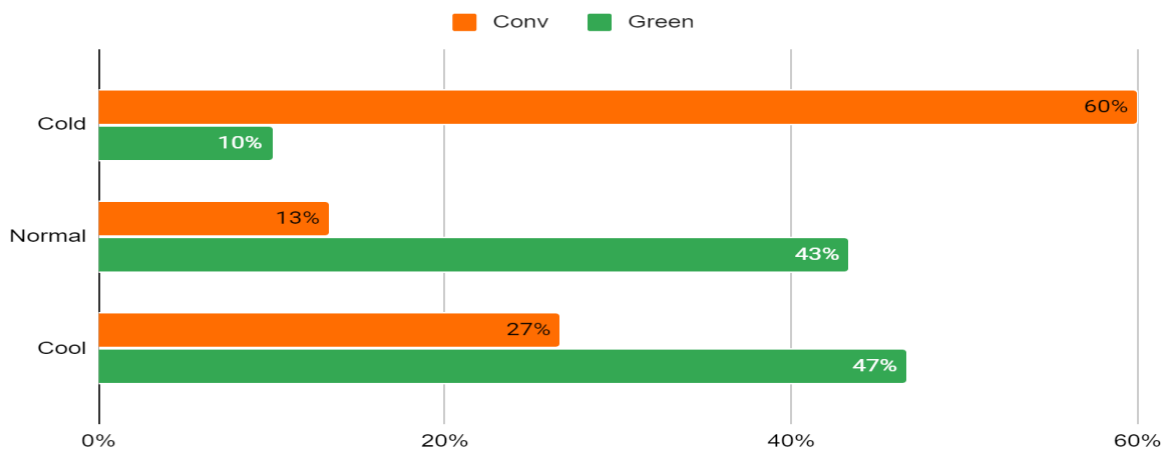


Fig. 1 Responses to 'how is the temperature in the office in winter?'



Figure 1 presents the reactions of users of conventional office buildings compared to green office buildings concerning the percentage of temperature as stated in the survey. The temperature is cool for 14 workers and normal for 13 participants of green offices and only cold for only 3 of them, While 12 participants of conventional buildings found the temperature to be normal and 18 said it was cold. From the above results, it emerges that despite the cold of winter, there was a comfortable temperature for 50% more workers in the green offices than conventional office buildings.

b) Use of heaters in winter

Survey question: Do you frequently use heater in winter?

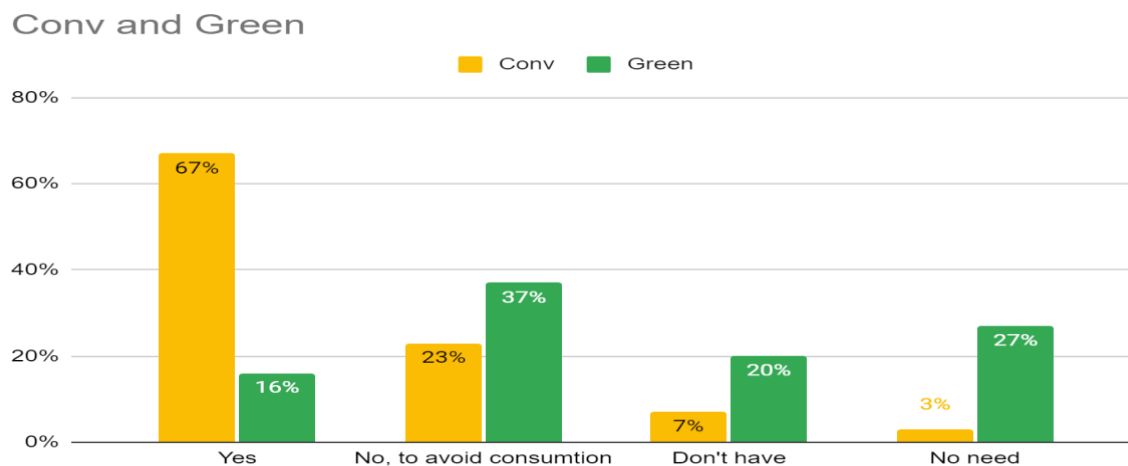


Fig 2.

Figure 2 shows the percentage of users of heaters in the green offices and the conventional offices during winter. Twenty out of thirty conventional office participants use heaters, and only five of the thirty green office participants use them in winter, which is 67% use in conventional offices versus 16% in green offices. The average consumption for most of the heaters used in offices is 1500 watts of electricity per hour. Therefore, green building offices in the study are saving about four times more energy compared to conventional heater usage.

c) Effects on body for staying long in Green office or Conventional office

Survey question: How do you feel in relation to the overall wellness in winter?

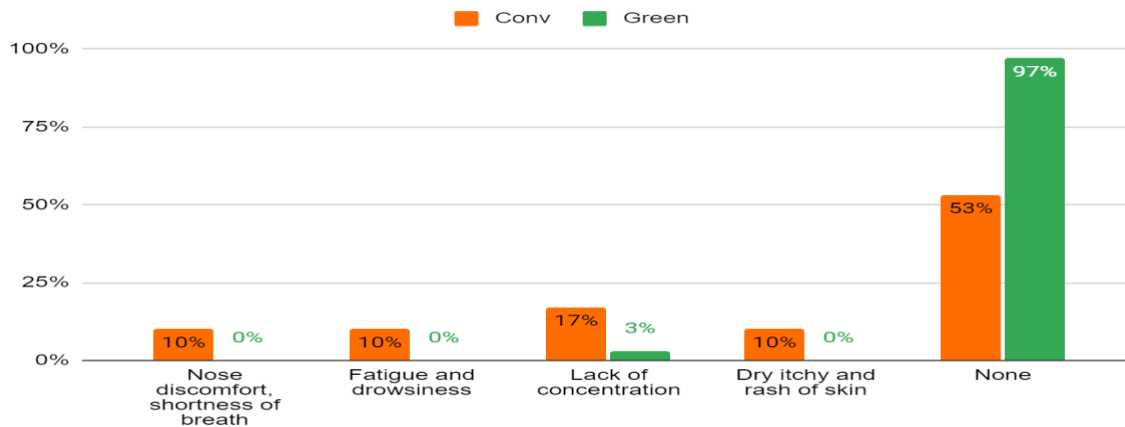


Fig 4

In figure 4, only one green office participant interviewed lost concentration after spending a long time in the office. Twenty-nine participants did not experience any physical or mental malaise. For the conventional building offices, sixteen out of thirty participants did not share any adverse effects. Still, five workers experienced lack of concentration, three had fatigue and drowsiness, three had nose discomfort, shortness of breath, and the other three had dry, itchy, and rash skin. Figure four shows that ninety-seven percent of green office users did not report undesirable effects, and only fifty-three percent of conventional office users did so. Compared to green offices, forty-four more participants have reported to have harmful effects in conventional offices.

c) Temperature in summer

Survey question: How is the temperature in summer?

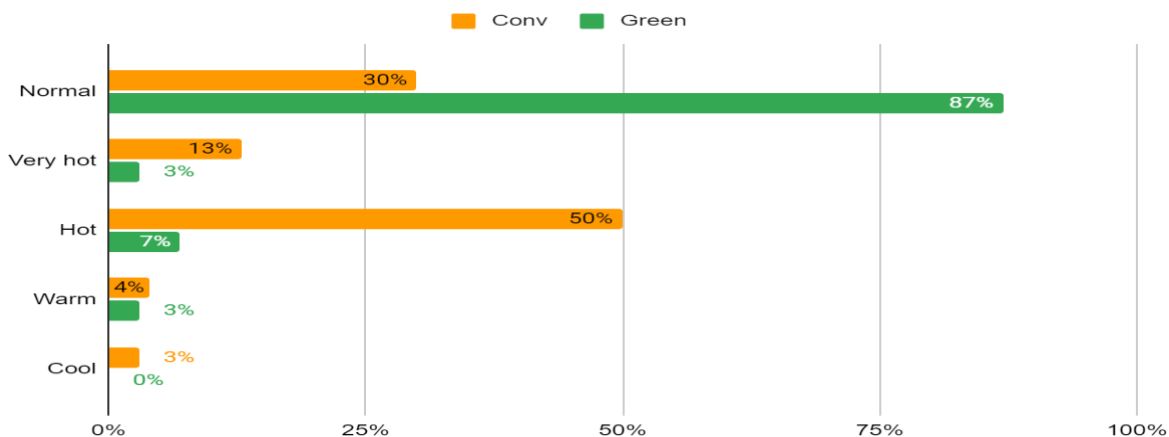


Fig 5

Nine participants from conventional offices reported the temperature to be normal; fifteen of them said it is hot, and for four participants, it was very hot while one found it warm. The temperature was normal for twenty-six participants from green building offices, hot for two, very hot for one, and warm for another. According to the participants, the temperature was comfortable when it was either normal or cool. Twenty-six participants from green building offices reported the temperature to be comfortable



while only ten from conventional building offices said so; looking at the results, it can be seen that the number of participants happy with the temperature in green offices is more than double the one in conventional ones.

d) Use of air conditioner

Survey question: Do you frequently use air conditioner in summer?

Conv and Green

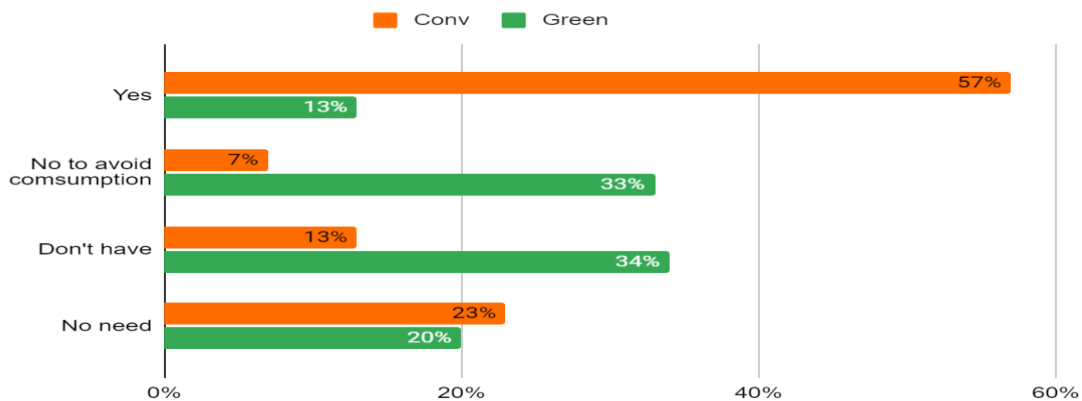


Fig 6.

Seventeen out of thirty, representing 57% of conventional office participants, use the air conditioner in summer. Thirteen out of thirty, which is 13% of workers in green building offices, use it to cool the indoor temperature. The air conditioner is one of the most energy-consuming equipment in the building. From the results given in figure 6, forty-four percent meaning approximately four times more air conditioners are used in conventional offices compared to green offices.

e) Feeling in the Conventional office

Survey question: How do you feel in relation to the overall wellness in summer?

Conv and Green

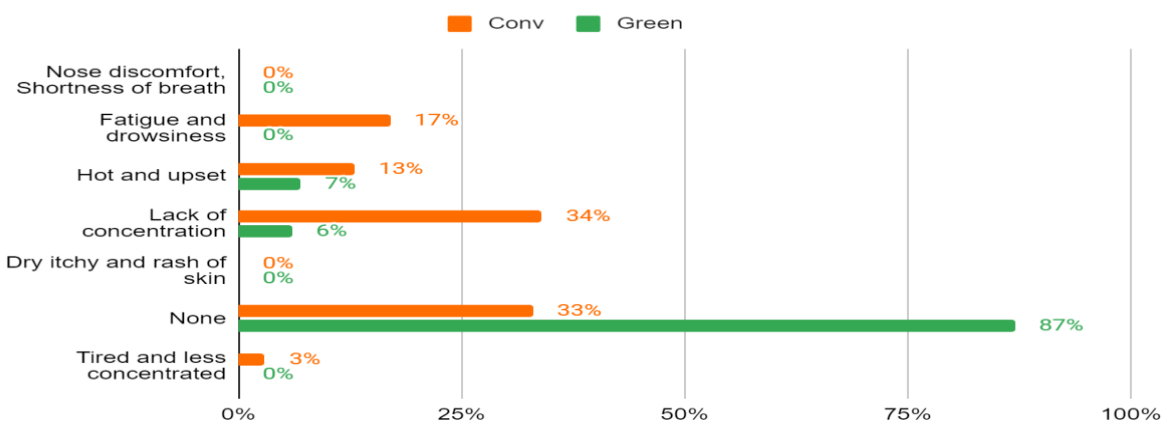


Fig 8



An overview of physical malaise happening frequently reported by occupants is given in figure 8, whereby five conventional office participants experienced fatigue and drowsiness, four were hot and upset, ten affected by lack of concentration, one was tired and less concentrated, but ten of the participants did not have any of those feelings while completing their daily task. For green building offices, only four participants, among whom two reported to lose concentration and the other two getting hot and upset, and the majority of about 26 participants being an equivalent of 87 percent of the workers, did not feel any physical or mental malaise while staying in the offices for long.

4. Discussions.

According to the literature, not all the green buildings have good air quality, but for the three buildings we have studied, sensors recorded 76 percent of time that CO₂ was greater than 700 ppm in the conventional building and only 26 percent for the green buildings. From the conventional building, during the same period of data collection 17 percent reported to feel fatigue and drowsiness, 10 percent often experienced nose discomfort and shortness to breathe while nobody said so in green buildings. Based on the combination of results obtained by sensors and survey, people might have more health effects in the conventional building because of the carbon dioxide's level of the workspace that exceeds the acceptable level. CO₂, although not causing physical effects such as an intense and immediate breathing problem, it is still dangerous because even at low concentrations can cause effects on cognitive functions and long-term impact on the health of occupants. Besides that, it causes Climate change which impacts both the weather and air quality, resulting in health issues.

A building is comfortable if the condition of the thermal environment expressed by the state of mind is satisfied (American Society of Heating, Refrigerating and Air-Conditioning Engineers) (ASHRAE 2013). Still, according to the findings the sensor deployed in the conventional building recorded 35 percent of time that temperature was uncomfortable versus 32 percent obtained in the green buildings, 53 percent of time of uncomfortable relative humidity versus 23 percent for green buildings. At the same time, 34 percent of occupants in the conventional building reported an experience of lack of concentration and only 6 percent said so in green buildings. 13 percent were more likely to feel very hot, upset as opposed to 7 percent for green buildings. A lot of literatures state that thermal discomfort lead to a disturbance of cognitive functions causing lower productivity but only a few of them have proven that green buildings have better thermal comfort than non-green buildings. The results from the three buildings we have studied reported green buildings to be more comfortable and have better air quality than the conventional, Nevertheless, it should be noted that the temperature range for achieving thermal comfort is different from a thermal comfort standard system to another since thermal comfort also goes with people's adaptability.

The results of this work have demonstrated how green buildings can positively benefit their users in terms of mental and physical health, as opposed to conventional buildings. Green buildings have primarily been proven to be beneficial to the well-being of their occupants, according to researches; However, the high cost of investment for a green building (G.S. Vyas, K.N. Jha, 2018) and the lack of sufficient information about it are things that prevent the adoption of green buildings by everyone; Government subsidies also have a significant impact on initial incremental costs (Alexeew, Carolin, & Zia, 2015); despite that, the well-being especially the health of the occupants are reasons for choosing green buildings.

5.Conclusion

In conclusion, Participants in this study reported better health, fewer symptoms in green buildings than in non-green buildings; which is supported by (Joseph G. Allen, Piers MacNaughton, 2015). There is still a need for future research to focus on the benefits of green buildings, especially on ways to reduce South



Africa's coal production using green building design principles. Improved IEQ in buildings correlates to improved health outcomes across several health indicators, including fewer sick building symptoms, fewer respiratory symptoms reported by building users, and better physical and mental health.

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An Evaluation of Manual Handling Training for Non-Lumbar Musculoskeletal Injury Prevention

Oliver Hewitt, Alexander Copping

University of Bath, UK

Correspondence: oh359@bath.ac.uk

ABSTRACT

Musculoskeletal disorders (MSDs) form one of the leading causes of occupational ill-health globally and affect workers of all ages, with construction having one of the highest rates of MSDs in the UK. Strenuous manual labour is often cited as the leading cause of these disorders, with manual handling training commonly implemented as part of an intervention strategy to combat this. Though these handling injuries are often associated with the lower back (lumbar) area of the body, MSDs may also occur in the 'non-lumbar' regions (encompassing the lower and upper limbs), areas which may be neglected by current training methods. This study aims to evaluate the effectiveness of current manual handling training in preventing non-lumbar injuries and propose factors to increase the efficacy of this intervention method. A case study approach has been adopted for this research, analysing the manual handling training utilised by a major multidisciplinary engineering firm through nine qualitative employee interviews. A general lack of effectiveness in transferring knowledge of non-lumbar injury was identified, despite the organisations' course being a clear improvement on commonly used methods of manual handling training. A lack of focus on the significance of non-lumbar disorders and variations in course content were identified as potential causative factors for this, with little reason for organisations to opt for more costly tailored training over less-effective generic courses. Recommendations for industry are proposed, with a focus on enhancing regulations to mandate better training practice, aiming to reduce injury in the short term before the fulfilment of the behavioural change required for the implementation of more radical solutions. Overall, this study contributes towards the body of literature around MSDs through analysing manual handling training from a non-lumbar perspective, an area previously underexamined in research.

Keywords: manual handling training, musculoskeletal, wellbeing, workplace injury.

INTRODUCTION

Musculoskeletal disorders (MSDs) are classified by the NHS (2020) as encompassing over 200 separate conditions affecting the joints, bones and muscles. These illnesses form one of the leading causes of occupational ill-health in the UK and are particularly prevalent in construction, with employees in this industry having one of the highest rates of musculoskeletal disorders of all occupations (Chant-Hall and Hall, 2019; HSE, 2020a). Manual labour and manual handling tasks are believed to be the leading cause of these disorders (Haslam et al., 2007; HSE, 2020a), with manual handling training mandated to form part of an intervention strategy as a legal requirement (HSE, 2016). This training aims to teach a method of handling that reduces forces in the body and is often associated with the prevention of lower back (lumbar) conditions. Injuries not related to the lower back (non-lumbar conditions) can also be developed from poor manual handling however, with the HSE listing the development of upper body disorders especially as a risk (HSE, 2020b).



This research explores the effectiveness of this training for preventing non-lumbar musculoskeletal injury, with this encompassing upper and lower body disorders (such as those affecting the shoulders, legs and arms). This has been undertaken utilising a case study into the training approach adopted by a major multidisciplinary engineering firm for site-based (industrial) handling operations through nine qualitative interviews, with findings formulated into a model of recommendations for industry.

CONTEXT

Development of MSDs

Though the developmental process for lumbar musculoskeletal disorders is well established, research into non-lumbar conditions is significantly less developed, with the majority of studies cross-sectional with limited scope for long-term analysis of injury development. Though Armstrong et al. (1993) proposes a developmental relationship for non-lumbar disorders between repetitive strenuous actions and a worsening musculoskeletal response at a rate dependent on the individual's anthropometry, as the pathogenesis is still not fully understood for some of these conditions this may not be universally applicable (Buckle and Devereux, 2002). More specific to construction, Borchardt, Yuan and Choi (2016) propose that forceful actions, awkward body postures and working in extreme temperatures are the most common risks for MSD development across all major trades, with this especially of note as the effect of the working environment is theorised to be currently neglected by many manual handling training sessions (Hermans, De Preter and Verschueren, 2012).

Methods of Intervention

As per the Health and Safety at Work etc. Act (1974), employers are required to make provisions to 'secure the health, safety and welfare' of employees. Improving the ergonomics of tasks through the use of lifting aids and tooling redesign is commonly used as a method of intervention in construction but has been found by numerous studies to provide minimal impact on MSD development, with Boschman, Frings-Dresen and Van der Molen (2015) theorising a lack of use due to poor practicality and inadequate training contributes towards this poor efficacy.

Though exercise programs have provided significantly more positive results, the necessity for continuous, regular sessions by trained instructors is a clear downside of this method (Kellett, Kellett and Nordholm, 1991). Novel 'interdisciplinary' manual handling courses aim to negate this through teaching exercise techniques for employees to undertake individually, with Garzillo et al. (2020) finding an increase in trainee satisfaction and participation rates in a nursing environment when combining traditional patient handling with this taught exercise training and team risk perception role playing activities. Though not currently implemented in a construction setting, this method is promising through forming an aligned sense of perceived risk in the team-based activity, with exercise training acting as a safeguard for lapses in good practice.

Training Models

Noe's Model of Motivational Factors (1986) has been adopted as a theoretical framework for the study, with the intention of grounding the research in proven social theory. This was deemed the most appropriate for this field due to the basis on the well-established Kirkpatrick's Four Levels of Learning Evaluation (1967), with Noe's model further expanding into the individual and organisational factors influencing the behavioural change required for training to be effective, as seen in Figure 1. The attitude towards change in an organisation is also critical to intervention effectiveness, with Whysall, Haslam and Haslam (2005) finding an increased progression in worker attitudes when measures were tailored to an organisations' State of Change, as per the model in Figure 2, but also a significant disconnect in perception of handling risks between workers and those in 'decision maker' roles.

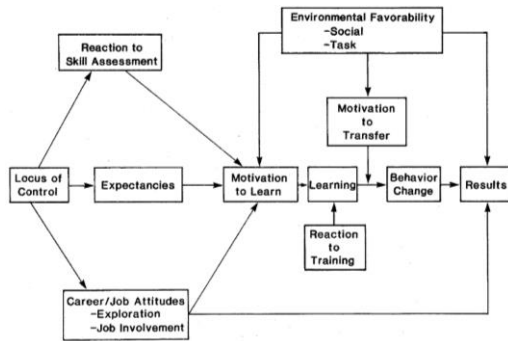


Figure 1 - Noe's Model of Motivational Factors (Noe and Schmitt, 1986)

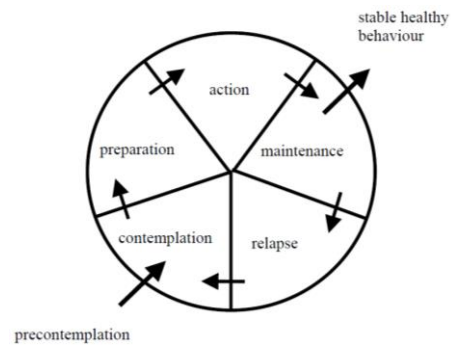


Figure 2 - The State of Change Process (Whysall, Haslam and Haslam, 2005)

Current Efficacy of Manual Handling Training

Previous studies have identified a generally poor effectiveness for manual handling training, with Hermans, De Preter and Verschueren (2012) finding that only a third of trainers studied made a preliminary visit to observe working patterns of their trainees. It is probable this resulted in the delivery of overly generic training, with this lack of relation to the employees' field unlikely to fulfil the Environmental Favourability factor of Noe's model required for skill transfer. This variation in course adequacy may be related to a lack of clear guidance on required content and delivery style, with the HSE (2016) neither publishing a 'best practice' course or requiring trainers to hold a formal qualification in the area, as with many other types of training in industry. A further disconnect between lumbar and non-lumbar disorders is also clear for delivered training, with the Arthritis and Musculoskeletal Alliance (ARMA) report (2019) noting that dexterity is often neglected in safety messages, with poor dexterity in the form of forceful pinching of items potentially resulting in upper limb MSD development (HSE, 2020b).

METHODOLOGY

A constructivist research philosophy was adopted, with primary data collected through a case study of a major UK-based multidisciplinary engineering firm using nine semi-structured qualitative interviews. Purposeful sampling with a maximum variation strategy was utilised, with the researchers' pre-existing knowledge of the organisation allowing 'information-rich' cases to be selected, maximising the range of viewpoints and depth of data collected (Patton, 2002).

Interview participants are detailed below in Table 1, with two interview guides used for this research. Though most questions were shared between these to allow key themes to be effectively analysed, additional questions for the manual handling trainers in interview guide T focus on the adequacy of the organisations' 'train the trainer' course, with guide G focussing on the interaction between intervention methods and training requirements for external contractors. Though interviewees were encouraged to provide in-depth answers, questions were formulated to keep interviews below an hour to prevent interviewee fatigue and associated acquiescence bias, with the ultimate range in duration between 30 and 50 minutes (Adams, 2015). Interview results were later analysed manually using content analysis. To prevent potential reputational damage to the organisation, both the name and any significant identifying factors for the company and interviewees have been omitted, with the anonymising of interviewees to their interview number also intended to promote a safe interview environment and persuade truthful representation of events (Gubrium et al., 2012).



Table 1: Interviewees' Roles and Position in Organisation

Interview Number	Job Role	Level in Organisation	Interview Guide	Tenure with company
1	Operational Safety Manager	Head of Department	G	2 Years
2	Health and Safety Training Manager	Head of Department	G	20 Years
3	Civil Engineering Graduate	Employee	T	2 Years
4	Trade Union H&S Co-ordinator	Employee (Industrial)	G	12 Years
5	Operations Cell Lead	Head of Department	T	31 Years
6	Electrical Production Manager	Manager	T	17 Years
7	Safety Practitioner	Employee	G	1 Year
8	Construction Health & Safety Specialist	Employee	G	1 Year
9	Safety Training Practitioner	Contractor	T	3 Years

RESULTS AND DISCUSSION

The organisation studied has adopted their manual handling training course from a major external health & safety training provider, with trained internal employees delivering the course. Both classroom-based and on-site course delivery methods are used by the organisation, with the majority of employees receiving the more traditional classroom-based course. This consists of a 3 and a half hour session with an approximately 50:50 split of theory and practical handling exercises, with the theory aspect covering injury mechanisms, defining what constitutes a handling activity, providing an insight into potential hazards and considerations, and defining the principles of safe lifting. As there is no standard manual handling course format currently stipulated by the HSE, a training session accredited by the Royal Society for the Prevention of Accidents (RoSPA) has been utilised to form comparisons in delivery style and content, due to the wide range of providers offering this course and the well-respected nature of the certifying organisation. Four key themes were identified through the interviews undertaken, with these and their underlying codes discussed below.

Focus on the Lower Body

The vast majority of interviewees described the course as focussing on the lower body, with the legs and lower back cited frequently. Though this is perhaps unsurprising, it is notable that the organisations' course does include a range of content on preventing non-lumbar injuries, with Table 2 identifying that the course slides cover nearly all of the risk factors identified for upper and lower limb disorders, more than the equivalent RoSPA course (HSE, 2020b, 2020c).

Table 2: Coverage of Non-Lumbar Risk Factors by Course

Risk Factor	Disorders Developed	Case Study Course	RoSPA Course	Discussed by Interviewees
Task repetition	All	Y	Y	1, 2, 3, 4, 8, 9
Uncomfortable or awkward working postures	All	Y	Y	2, 4, 5, 6, 7, 8, 9
Forceful pinching, gripping or manipulation of items	Dexterity	Y	N	None
Handling heavy items	All	Y	Y	1, 2, 3, 4, 5, 7, 8, 9
Carrying out a task for an extended period of time	Upper & Lower Limb	Y	N	1, 2, 3, 4, 9



Working in uncomfortable temperatures	Dexterity	Y	Y	1
Working in dim light, shadow or glare	Upper Limb	Y	Y	None
A lack of control over the work rate, or any excessive task demands	All	N	N	4, 5, 7, 8
Individual capability	All	Y	Y	2, 5, 7, 8, 9
Repetitive kneeling and/or squatting	Lower Limb	N	N	None
Climbing stairs or ladders	Lower Limb	Y	Y	1, 3
Prolonged standing	Lower Limb	N	N	None

The lack of knowledge transfer surrounding non-lumbar conditions to the interviewees is however concerning, with the least frequently mentioned factors in Table 2 relating mainly to dexterity, as proposed by the ARMA report (2019), and lower limb disorders. Though this is potentially unexpected, with content on the legs frequently mentioned both by interviewees and in the course itself, this appears to be confined only to their use as muscles for lifting. While lower limb disorders account for only 19% of work-related MSDs (HSE, 2020d), potentially explaining their lack of inclusion in the course, they still pose a clear risk and hence this training should cover these disorders as a minimum. A lack of connection between these risk factors and conditions they may cause is also visible in both courses, with course slides purely stating these factors without further explaining how or what injuries they can lead to. This may act to further limit the course effectiveness through negatively affecting the Motivation to Transfer sector of Noe's model.

The use of simple and memorable terminology is an area in which the organisations' course appears to be significantly more effective than alternative courses offered in industry, with the use of clear graphics to explain complex injuries, such as disc herniation, identified by interviewees:

'...the actual doughnut example where if you squash a doughnut, the jam comes out. And that was quite clear for everybody in terms of how you look after your back' (Interviewee 5)

Though focussed on the spine in this case, explaining how non-lumbar injuries occur in a similar, less scientific manner may also improve training effectiveness for the prevention of these disorders through improving employee understanding of injury mechanisms and prevention. This is an area where training such as the RoSPA course is clearly lacking, with course slides both unengaging and focussing mainly on the biological aspects of injury, with minimal relation to handling activities.

Responsive Nature of Interventions

The use of health monitoring through examining accident reports was frequently raised by interviewees, with multiple changes made to the course since being implemented in response to injury trends and poor compliance. Though the efficacy of this monitoring may be questioned due to the lack of a 'reporting culture' in the organisation, as detailed by interviewees 1 and 8, and the complexities and cost of monitoring these reports, with changing the behaviour of trainees acknowledged by interviewee 9 as 'the hardest thing to do in health and safety', providing a way of measuring this behavioural change is significant to ensure that delivered training is having an effect. Notably, though the reviewing of controls is required by the Management of Health and Safety at Work Regulations (1999) if they are suspected to no longer be sufficient, monitoring the effectiveness of implemented interventions through methods such as health monitoring is not currently a legal requirement (HSE, 2020e). Without monitoring the effects of training, it is unlikely that there will be adequate information to determine the sufficiency of a control



method, with this possibly leading to insufficient training methods being utilised unknowingly by organisations.

Role Focus and Variability

Course Variation

A source of variability identified for the training delivered by the organisation arose from the use of both site-based and classroom delivery methods, with the fixed three and a half hour duration for the classroom-based course significantly more than the one hour site-based course delivered by interviewee 2. Though issues surrounding multiple delivery methods are potentially a more unique issue to larger organisations with a more varied workforce, this issue is also observable through differences in training approaches between contractors. With construction sites generally containing multiple different organisations working in tandem, there is a high potential for differences in behaviour to be transmitted between companies, with ARMA (2019) reflecting that workers tend to work within the culture of the site they are operating in. As there is minimal guidance provided by the HSE (2016) on course content and delivery, a wide range of delivery styles are available – though these may all fulfil the legal requirements for this training, as illustrated with the two courses analysed, there are clear differences in both content and effectiveness. This issue of adequacy of training courses is raised as a potential issue especially when employing sub-contractors:

‘...unless you can go to their training, you’ve got to sort of trust their trainer. Like I say, it’s not like certain things where you might have a City and Guilds or CITB course... there’s no proper training criteria, really.’ (Interviewee 8)

As noted above, this lack of a clear ‘best practice’ format to follow possibly provides a greater opportunity for organisations to choose a lower cost but less effective method of training whilst still meeting regulatory guidelines. Though this may suggest a need for stricter guidelines in this area, it is noteworthy that most interviewees believed that the current regulations and guidance are sufficient. Although this response is somewhat unexpected, it is significant that the organisation studied benefits from a large Health and Safety team due to the scale of their workforce, with many companies in construction falling into the SME bracket and potentially having limited access to the occupational health services which may advise on these training decisions (ARMA, 2019). Through increasing the clarity of the current requirements to promote compliance, this is therefore an area in which providing a form of ‘good practice’ manual handling training may be of benefit.

Competency

The issue of competency, both in trained employees and trainers, is a theme raised frequently in the interviews conducted, especially in relation to online manual handling training:

‘there are plenty of online manual handling courses [available]... it would be very difficult to say they’re not suitable’ (Interviewee 9)

Though prevalent, online courses notably don’t meet the current training guidance published by the HSE (2016), which stipulates the inclusion of ‘practical work’. With handling activities being a predominantly physical activity, this practical element forms a key part of the Environmental Favourability sector of Noe’s model for this course, making it unlikely that these online sessions will be effective. For this training to be considered as less of a ‘tick-box exercise’, as noted by interviewee 9, it is therefore apparent that a firmer regulatory stance should be taken towards online-only training through the implementation of a clear ‘good practice’ course format, as previously discussed.



The competency of manual handling trainers was also brought into question by the interviewed employees, with the lack of training requirements for this course raised:

'confined space... the people that are delivering that course have to be qualified as well, where the 'train the trainer' training is what you're meant to get to deliver manual handling training, but it's not necessarily a requirement' (Interviewee 8)

Though both of the courses analysed require trainers to attend formal training prior to delivering courses, this is not currently a legal requirement, with guidance from the HSE (2016) purely placing an onus on the organisation to ensure 'an adequate level of competence' of the trainer. This concept of measuring competence is somewhat contentious in industry, with the HSE (2013) definition of 'the combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task safely' being relatively open to interpretation. Though Pye, Pye and Legard (2011) note that competence cannot end with training or examination, mandating trainers attend a 'train the trainer' course may increase clarity for employers hiring manual handling trainers, whilst at a minimum ensuring that trainers follow a set standard of training.

Training Relation to Job Role

A clear area of good practice was the relation of the organisations' training to job roles, with the use of videos filmed on the site itself and the opportunity to undertake practical training in the employees' place of work having a positive impact on employee confidence in the techniques taught through an increase in the Environmental Favourability and Motivation to Transfer sectors of Noe's model:

'So the props that they were using to be trained was actually their kit... that gave them huge amounts of confidence that they knew what to do and how to show others' (Interviewee 5)

Though guidance from the HSE (2016) suggests that courses should 'relate to what workers actually do', this is perhaps interpreted more loosely by the equivalent RoSPA course, which through aiming to fulfil the requirements for multiple industries appears overly generic. It is however noteworthy that many of the positive comments of the organisations' course revolved around the site-based delivery method, not the custom videos utilised by the more-traditional classroom-based course:

'what should happen is the trainer should go and meet the gang... and go, right, this is where we work, teach us the techniques we need to be taught... I think it is outdated, the way it [classroom-based training] is' (Interviewee 4)

With classroom-based courses often found to be 'pretty dull', as noted by interviewee 5, there is a potential poor fulfilment of the Expectancies factor of Noe's model with this method of delivery. The provision of tailored, site specific videos, though improving effectiveness through other means, are unlikely to improve this negative perception of the course, with the production of these videos also likely to be costly and as a result unattainable by all but the largest organisations, potentially making site-based methods of course delivery more favourable.

Culture Surrounding Manual Handling

Assessment and Avoidance of Handling

Though improvements in site culture were stressed by many interviewees, especially with regards to the receptiveness of employees to training, a regular theme involved poor compliance with the use of Point of Work Safety Assessments (POWSA), a tool used by the organisation for assessing risk prior to undertaking a task:



'... that's probably where we are with manual handling - filling in the POWSA, not necessarily understanding the risks, or if they are, they've just become accustomed to the risks for manual handling and then just carrying on' (Interviewee 1)

Though this places the onus for this non-compliance on industrial employees, with interviewee 7 noting that course content on assessing risk is *'geared towards a line manager overseeing a task... rather than at the POWSA stage'*, this may be an example of the manager-employee disconnect identified by Whysall, Haslam and Haslam (2005), with a lack of experience in task assessment potentially leaving the Environmental Favourability sector of Noe's model unfulfilled for this element. Through providing both experience of assessing risk in practice and a method for trainers to examine the abilities of employees to assess risk in the workplace, this a situation where the role-playing risk perception activity proposed by Garzillo et al. (2020) may increase course effectiveness.

The use of lifting aids was also raised by interviewees as an area with mixed compliance, with project time pressures negatively impacting good handling practice identified by interviewees:

'...part of it is just personal risk that people are willing to take because things take so long to get organised. You know, you could slow something down for possibly days just to get a pallet moved' (Interviewee 8)

Though in this case the onus may be on managers to prevent project pressures impeding good handling practice, it is of interest that the accounts of positive compliance mostly came from the trainers delivering site-based training, with this method training employees directly in the use of lifting aids, unlike in the classroom-based sessions. With a lack of training in these aids visible throughout literature as contributing to a poor intervention effectiveness (Boschman, Frings-Dresen and Van der Molen, 2015) this initially lends further weight to mandating on-site manual handling training, though as this good practice was only identified by manual handling trainers this finding may be affected by bias due to their personal involvement in the compliance of employees with this equipment.

Exercise Training

Exercise training was discussed by many of the employees interviewed as an example of good practice, with the course used by the organisation notably including a section on warming up prior to undertaking strenuous handling activities, similar to that proposed by Garzillo et al. (2020). With only interviewee 7 acknowledging this section of the course however, the effectiveness in this case is questionable, with a poor site psychosocial culture suggested as a causative factor:

'... people won't want to do things, like softer sort of exercises that are really just about looking after themselves' (Interviewee 7)

With interviewee 2 also noting that a past attempt of introducing standalone exercise sessions *'lasted all of a couple of months'*, culture is clearly a major barrier in the organisation to effectively implementing this intervention method. With the effectiveness of training dependent on the Social Favourability factor of applying the trained skills, this environment suggests exercise interventions are not currently effective. Though the improvements discussed in this study may act to expediate this behavioural change, it is noteworthy that changing behaviours is not a quick process, with employees interviewed by Lunt et al. (2008) suggesting a timescale of 5 to 10 years for a full organisational culture change. As a result, the implementation of exercise training may not yet be appropriate, with a focus on changing perceptions surrounding manual handling currently more pressing.

Managerial Buy-In

The requirement of managers to ‘buy-in’ to methods of intervention was regularly raised in interviews, both through the associated cost and time, but also through a willingness to change procedure:

*‘he just didn’t want somebody... coming back and teaching the lads different techniques, which would mean we won’t be able to use the equipment which he dictated that we had to use’
(Interviewee 4)*

With managers generally having the final say on decisions relating to safety and workplace changes, they must undergo the same behavioural change as employees with regards to perception of handling issues, something that appears not to have taken place in the example given above. Though there is some potential bias in this statement due to the personal aspect of the incident, this does highlight a potential disconnect in the State of Change of employees and managers, with interviewee 7 further noting some employees felt that *‘they’re not going to get the support from the business... to follow the training’*, with this cynicism suggesting a current course ineffectiveness through the unfulfillment of the Social Favourability factor of Noe’s model. It may be theorised that this disconnect is due to the course prioritising site-based workers, with interviewee 8 noting the course is *‘more for industrials’* than managers. Though guidance from the HSE (2016) does propose that supervisors should be ‘aware of practices that have been taught to workers’, mandating employees at all levels of the organisation attend manual handling training may help to reduce this disconnect in behavioural state through providing all employees with equal knowledge in the risks of handling activities.

Verification of Findings

As a final step of verification, the results were validated by an experienced practitioner and researcher in the field of work-related musculoskeletal injury external to the organisation studied, as per the Elliott, Fischer and Rennie (1999) ‘credibility check’ process. Though broadly agreeing with the findings of this paper, they noted that training needs to be contextualised in a suitable way for the employee, with relation of handling activities to a job role perhaps not always able to fulfil this. This comment has been incorporated into the final model of recommendations proposed by this study for the improvement of manual handling training in non-lumbar disorder prevention, shown in Figure 3, with the improvements discussed in detail in this paper highlighted.

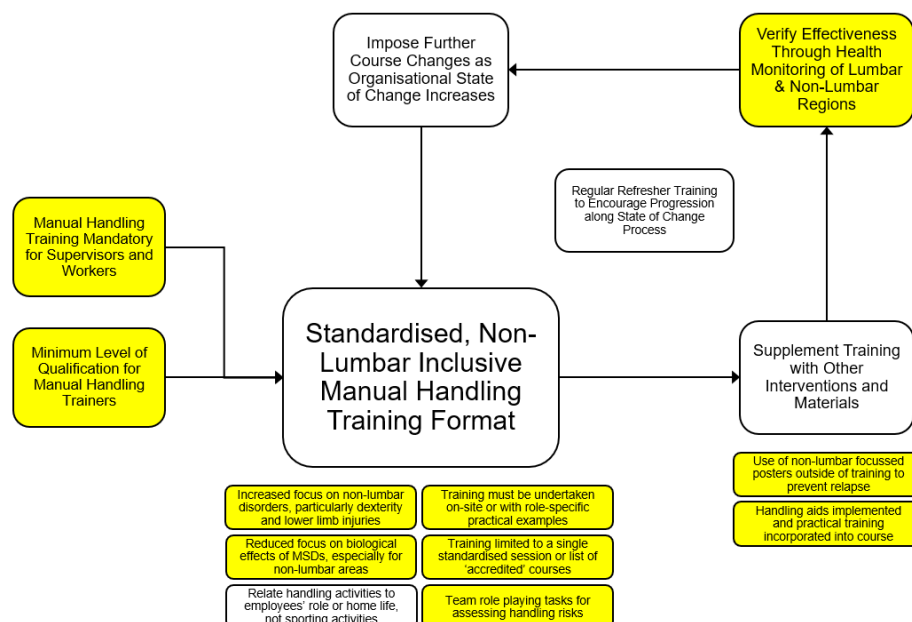


Figure 3 - Model of Improvements for Manual Handling Training Effectiveness in Non-Lumbar Disorder Prevention



CONCLUSION

It is evident from the interviews undertaken that, though the method of training utilised by the organisation studied is a significant improvement on standard generic manual handling courses, its effectiveness in preventing non-lumbar conditions is still somewhat lacking. The recommendations proposed by this study focus mainly on the enhancement of regulations to mandate better training practice, aiming to reduce non-lumbar injury in the short term before the behavioural change required for the implementation of more radical solutions, such as the exercise training proposed by Garzillo et al. (2020), is in place. There are several opportunities for future research in this field, with an investigation into the efficacy of manual handling training delivered by smaller organisations especially of interest. With this study focussing on initial improvements for the efficacy of this training, the majority of these being regulatory focussed, another potential area of research may focus on the longer-term effectiveness of more radical methods of training, such as the inclusion of exercise interventions as per Garzillo et al. (2020), with a focus on organisations already in the higher Action or Maintenance States of Change (Whysall, Haslam and Haslam, 2005). Analysing the effectiveness of a course which incorporates these findings with a longitudinal observational method may also be of interest, with this potentially providing a further level of verification to these results.

This study has contributed towards the body of literature around MSDs through analysing manual handling training from a non-lumbar perspective, an area previously underexamined in research. Though the suggestions surrounding managerial involvement in training and the treatment of training as a continual process are shared by the pre-existing lumbar-focussed study by Haslam et al. (2007), the majority of recommendations identified are novel and provide additional scope to improve the effectiveness of this training for non-lumbar disorders in particular.

There are however limitations which must be considered when discussing the obtained findings. Firstly, the multidisciplinary engineering organisation utilised for this case study may have held different training priorities than a purely construction-based organisation, such as a need for increased versatility to cope with a more varied workforce. Due to the large size of the organisation, it is also possible that these results may not be directly applicable to SMEs, due to the lower capital available for training and generally more transient nature of staff in this scale of organisation (ARMA, 2019). The use of a qualitative interview approach is also potentially more susceptible to bias than an equivalent observational or quantitative study, with previous links between the researcher and organisation studied possibly exacerbating this. Lastly, it is notable that this field is a potentially sensitive area for organisations, hence interviewees may have held back information for fear of reprisal from their employer.

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